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# STARCH PRODUCTS

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*Frontispiece*

GERARDE WITH BRANCH OF POTATO
(Note the Elizabethan starched ruff)

PITMAN'S COMMON COMMODITIES
AND INDUSTRIES

# STARCH
# AND
# STARCH PRODUCTS

BY

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# PREFACE

The following pages are an attempt to collect such facts concerning starch and its manufacture as appear to be of general interest, and, at the same time, to draw attention to the importance of this widely distributed substance. The writer has, of set purpose, refrained to confine himself either to the chemistry, or the technology of the subject, but has made many references to botanical, entomological, and other fields, such as folk-lore, considering that they have equal claims upon the interest of the general reader. For it seems to him hardly necessary to point out that the divisions of scientific study have been made for convenience only, and should not, therefore, be treated as having any other foundation.

This small book is the outcome of a collection of notes made in the first instance without any idea of publication, and the sources are not known in all cases. The following works have been of much help: *The World's Commercial Products*; *Stärkefabrikation* (Rehwald); *Stärkezucker* (Bersch); *Fabrication de la Glucose* (Fritsch); *Fabrication de la Fecule* (Fritsch); and *Le Manioc* (Hubert and Dupre).

The writer wishes to express his gratitude to the following individuals and firms for their kindness in allowing him to reproduce illustrations of which they possess the copyright:—To the Controller of H.M.S. Stationery Office for permission to use Figs. 2 and 14; to Messrs. Macmillan for Fig 7; and to Messrs. Blair, Campbell, and Maclean for Figs. 15, 16, 17, 18, and 19.

LIVERPOOL, 1922.

# CONTENTS

PREFACE . . . . . . . vii
FOREWORD . . . . . . . xiii
I. HISTORICAL . . . . . . . . 1
II. GENERAL PROPERTIES . . . . . 8
III. POTATO STARCH . . . . . . . 20
IV. CEREAL STARCHES . . . . . . 33
V. MAIZE AND MILLETS . . . . 45
VI. RICE . . . . . . . 55
VII. SAGO, YAM, AND OTHER STARCHES . 68
VIII. ARROWROOT, CASSAVA, TAPIOCA . 74
IX. BLEACHING, COLOURING, ETC. . . 85
X. GLUCOSE, DEXTRIN, GUM . . . 91
XI. FERMENTATION PRODUCTS . . . 103
INDEX . . . . . . . 117

# ILLUSTRATIONS

FIG. PAGE
GERARDE HOLDING BRANCH OF POTATO AND WEARING STARCHED RUFF . . *Frontispiece*
1. OLD METHODS USED IN STARCH MANUFACTURE . 27
2. CYLINDRICAL SIEVE . . . . . 29
3. MAIZE PLANT . . . . . . . . 47
4. KAFFIR WOMEN GRINDING MAIZE . . . 49
5. CHINAMEN THRESHING MILLET . . . 51
6. MILLET AND SORGHUM FIELDS NEAR PEKIN . 53
7. TERRACED RICE FIELDS . . . . . . 57
8. IRRIGATION PUMP, WORKED BY THE FEET . 59
9. CHILDREN POUNDING RICE IN INDIA . . 61
10. CLEANING AND POUNDING RICE AT MANILA . 63
11. ZAMIA PALM (FEMALE) . . . . . . 71
12. ZAMIA PALM (MALE) . . . . . . 71
13. MANIOC PLANT . . . . . . . 77
14. APPARATUS FOR CONVERSION OF STARCH INTO DEXTRIN . . . . . . . . 95
15. CONVERTER . . . . . . . . 97
16. VERTICAL TRIPLE EVAPORATOR . . . 99
17. MULTIPLE TRIPLE-FILM EVAPORATOR . . 101
18. TRIPLE COLUMN STILL . . . . . . 111
19. DOUBLE COLUMN STILL . . . . . . 113

# FOREWORD

"BUT wot you what? The devil as he in the fulnesse of his malice, first invented those great ruffes, so hath he now found out also two great pillers to beare up and maintaine his kingdom of pride withall (for the devil is a kyng and prince over all pride). The one arch or piller wherewith the devil's kingdom of great ruffes is underpropped is a certain kind of liquid matter called starch, wherein the devil hath willed them to wash and dive their ruffes, which being drie will stand stiff and inflexible about their neckes.

". . . and then lest they should fall down they are smeared and startched in the devil's liquor, I mean startch.

". . . and this startch they make of divers substances, sometimes of wheate flower, of branne and other graines; sometimes of roots and other things: of all colours and hues, as white, redde, blewe, purple, and the like."

*Stubbs. Anatomie of Abuses*, 1583.

"Sufficeth them, having starched their beards most curiously, to make a peripateticall path into the inner parts of the Citie."

*Nashe. Menophon*, 1589

"Since yellow bandes, and saffroned chaperoones came up, is not above two yeeres past."

*Owle's Almanacke*, 1618.

# STARCH

## CHAPTER I

### HISTORICAL

It is not possible to fix with any degree of certainty the period at which the substance now known as starch was first recognized. But this absence of knowledge is easily accounted for, because starch is, and has always been, one of the most important as well as one of the most widely occurring products of the vegetable kingdom, and has always constituted a large proportion of the staple diet of the human race. It is a matter of experience and of fact that the products of plant life which form the principal food in all parts of the world have always been those which possess a high starch-content. Every individual both in the most primitive as well as in the most civilized nation depends, and has depended, for his sustenance on the important starch-producing plants. For, as De Candolle (*Origin of Cultivated Plants*) remarks: "Men have not discovered and cultivated during the last 2,000 years a single species which can rival maize, rice, sweet potato, potato, bread fruit, date, cereals, millets, sorghums, banana, soy. These date from 3,000–5,000 years, perhaps in some cases 6,000 years."

The above-mentioned cereals, maize, rice, millet, and sorghum, are members of the great family of grasses which have been cultivated by man from time immemorial, the name cereal in itself indicating the great value attached to such plants in early historic times. For it is derived from Ceres, as the Romans called her—the Demeter of the Greeks—the patron-goddess of agriculture, and of all fruits of the earth

But before we proceed further we might ask "What is Starch?" A modern definition explains it thus: "Starch is a carbohydrate of undetermined chemical constitution, found in granules of varying size in different plants, cereals containing the highest proportion; for instance, rice approximately 76 per cent, maize and wheat 70 per cent, peas 50 per cent, and potatoes 20 per cent." But the word itself, now in popular language connoting the well-known property made use of in the stiffening of linen, has been considered by some writers to imply 'the strongest portion' of the meal.[1] References to starch both as food and a stiffening material are found in many classical writers of early date. Though the starch in our food is usually in admixture with other plant constituents, and, therefore, in many cases the value of the starchy portion of the raw vegetable material may be increased by removing husks, etc., by some sort of milling process, the Greek name *ἀμυλον* (Latin *amylum*), from *ἀ* privative, and *μυλον* a millstone, draws attention to the fact that starch may also be obtained without the necessity of grinding. "Amulon" is described as a fine meal, and also as "a kind of cake made with barley which is steeped for several days, and, before it becomes sour, is dried on linen and made firm by the sun. It is so called because it is made without a mill. It is used in medicine, in food (for which purpose it is customary to boil it in milk), and," Cato adds, "to-day we employ starch to stiffen clean linen." Cato (234–149 B.C.), De Re Rustica.

---

[1] The word *Starch* seems to be derived from the Anglo-Saxon *Stearc*, and to mean originally that which is or makes strong, or stiff; cf. *Stark*, which comes from the same root *starr*, stiff.

"Nis non so strong, ne sterch, ne kene
That mai ago death's wither blench." (MS. Cott. Calig., Halliwell).

"Many a nobleman lies stark and stiff" (Shakespeare).

Pliny (A.D. 23–79) attributes the discovery of starch manufacture to the inhabitants of the island of Chios, where also, in later times, the best kinds were made, the Cretan and Egyptian products being given as the next best varieties.

Celsus (A.D. 29–60), who made "a pure and elegant translation" of the writings of Hippocrates into Latin, classes amylum in the group of wholesome and easily digested foods. Dioscorides also has similar remarks.

Various dates have been assigned by different writers for its introduction into Northern Europe as a stiffening agent for linen. In the fourteenth century mention is made of a kind of starch used by weavers in Flanders (W. Flemish "Sterksel"). An early English reference is found in a M.S., Norwich Sacrist's Roll of 1390, "Vestiarium: pro coole, pro starchyng. Viii$^{d}$." But the author of this work is of the opinion that the earliest English description occurs in Aungiers' account of Syon Monastery, founded at Isleworth in 1415. The book was apparently published in 1440, and, in an addendum to the "Rules of St. Briget," we read: "The Office of Sexteyne—When the sexteyne of the brether syde hath washe the corporas ones, she withe help of her susters schall washe them, sterch them, drye them . . . . nor sterche them but with sterche made of herbes only."

At about the same date the author of *Promptorium parvulorum*, speaks of "Starche for Kyrcheys."

The following is a translation of a latin recipe for starch-making (Sloan MSS., 3,548, f. 102): "Take a quantity of bran and boil it in clean water and allow it to stand for three days or longer, until the water is bitter or sour: then squeeze out the water from the bran, and place your cloth, muslin, buckran-ram'), thread or what you will, in the clear liquor, and afterwards dry it and smooth it with a stone 'that is, polish the surface with a slekystone.'"

There is considerable variation in the years assigned to the introduction of starch into England, which agree neither amongst themselves nor with the earlier date already given. One writer says that starch was first heard of in England in 1561, and was not much used until 1564, when Mistress Dinghem van der Plassen, a Fleming, was brought over to London as professor of laundry-work, and to teach publicly the art of starching. Her reception seems to have been comparable to that now given to persons of highest rank.

Stowe may be referring to this lady when he wrote in 1614 that a Dutchwoman undertook to teach this art, and that her usual price was four or five pounds to teach how to starch, and twenty shillings how to seethe the starch. But another Dutchwoman, named Guilham, wife of Queen Elizabeth's coachman, won the favour of this sovereign and became superintendent of the royal laundries. Her reputation extended throughout the kingdom, and titled ladies came to take lessons from her. About this time there were to be seen in the most aristocratic residences tubs and other utensils necessary for the preparation of starch, which are nowadays banished to the laundries. Washing, drying, hanging out and ironing were performed in the presence of nobles, as to-day are music and other arts.

Fosbroke also gives the year 1534 as the time when starches of various colours were imported from Holland, the yellow variety being esteemed the best for ruffs and other articles. Stubbs, an exponent of extreme puritanic views, has been quoted by way of foreword.

In *The World Tossed at Tennis*, printed in 1620, five different coloured starches are personified and introduced as contending for superiority.

A blue-coloured starch was affected by the Puritans, and this may account for Queen Elizabeth's aversion, in her old age, to blued linen, going even so far as to forbid the use of it. But the nobility paid no attention to this prohibition, therefore an edict was issued, which was read from the pulpit in the Church of St. Botolph, Aldgate, 27th June, 1596. "Our gracious sovereign forbade some time ago any man or woman of whatever rank to wear blued linen. Several citizens have dared to violate my royal command. Therefore it is the grave desire and formal order of Her Majesty that it be made known to all people of every rank and sex, that whosoever maketh use of blued body linen will incur the displeasure of the Queen. The offender will be liable to the penalty of imprisonment, the term of which will be decided by Her Majesty. Therefore let everyone so act as not to be punished. Given at Guildhall, 23 June, 1596."

The fashion, affected by both the great and small, by the refined and the vulgar, of having their ruffs and linen stiffened with a yellow starch, was an object of satire to the wits of Ben Jonson's age. The characters, Fabian Fitzdoltrel and Sir Paul Eitherside, in Jonson's *The Devil is an Ass*, are made to say "Or fashion now they take from us. Carmen are got into the yellow starch and chimney-sweepers to their tobacco and strong waters." In another play, "Trincalo, what price bears wheat and saffron, that your bandes are so yellow?" or again, "Who starches you?"

But it became for a time disreputable after 1615, when Mrs. Turner, employed by the Countess of Essex in the poisoning of Sir Thomas Overbury, ascended the scaffold with a yellow-starched ruff about her neck.

Starch-making was among the obnoxious monopolies revoked by Queen Elizabeth in 1601. Her successor attributed "great mischief" to that action, and denounced the "excessive disorderly and inordinate making of starch in many places of this Realm, by converting and consuming of great quantities of wheat and other corn fit for man's food and sustenance into starch, and also by the noisome and offensive savours, and dangerous and contagious stench arising from the making thereof in sundry places unmeet for the purpose." Having first prohibited all starch-making throughout the country, James I, in 1607, allowed a restricted and supervised manufacture, directing that bran and not wheat should be used. A few months later the trade was placed under the control of "the Master, Wardens, Assistants and Commonalty of the Art or Mystery of Starchmakers of the City of London. The London grocers, who were beginning to make their own starch, opposed the incorporation, prophesying increased prices. The Company agreed to pay 5s. per cwt. of starch in compensation for loss of custom; but in 1610, all starch-making in England and the purchase of English starch was again forbidden; because wheat and edible flours were still being used. In 1622, however, the Company was revived, starch-making by non-members being threatened by the Star Chamber, and after the Restoration it was re-incorporated.

The use, however, of starch on anything approaching a large scale is of quite late date, it being looked upon until recently as an article of luxury only. For though the manufacture was carried on in Holland in the sixteenth century, it was in quite a small way, and not until about the middle of the nineteenth did uses, other than those arising in the laundry, boudoir, or kitchen, come into being.

An English patent was taken out in 1707 by Samuel Newton and others for the manufacture of starch. In 1795 John Hart published "An Address to the Public on the Starch and Hair Powder Manufacturers," strongly advising the consumption of "damaged corn, such as is unfit for the purposes of bread"; in 1796 John Ryder issued "Some Account of the Maranta or Indian Arrow-root, in which it is considered and recommended as a substitute for starch prepared from corn," and described the process of preparing it; in 1812 Kirchoff's "Production of Sugar from the starch of wheat and of potatoes by the agency of sulphuric acid" was announced in the *Philosophical Magazine*. In 1796 Murray suggested a method of utilizing the horse-chestnut; in 1823 Thomas Wickham used rice. Further improvements were made by Orlando Jones in 1839.

A patent of Coleman, of 1841, relates to the preparation of starch from rice by a fermentation process, and one of Brown and Polson, of 1854, to the subject of maize starch.

The chief uses at the present time are in the textile industries and paper manufacture, in making gums, and dextrin, also, though less directly, in the preparation of beers and alcohol, by fermentation. For certain classes of work, as the dusting of foundry moulds, impure starch is used, the Montyon prize of 1780 being awarded by the Academy of Sciences to Roux for this invention.

# CHAPTER II

## GENERAL PROPERTIES

ALL plants in which the green colouring matter known as chlorophyll is present contain starch, but the practical sources of supply are restricted to (*a*) cereals, such as wheat, rice, maize, etc ; (*b*) tubers and roots, such as potato and manioc ; (*c*) the pith of certain trees, as the sago palm.

The choice of raw materials for the manufacture is restricted also (*a*) by the difficulties of removing detrimental substances which accompany it in the plant, and naturally is also (*b*) largely determined by the amount of starch actually present.

From the chemical standpoint, starch is composed of the elements carbon, hydrogen, and oxygen associated in the proportions indicated by the formula $(C_6H_{10}O_5)_n$. The value of " *n* " is almost certainly not less than four, i.e. $C_{24}H_{40}O_{20}$, and probably as high as thirty, i.e. $C_{180}H_{300}O_{150}$. It possesses the same general formula as cellulose, dextrin, lignin, inulin, and lichenin.

Inulin occurs in the dahlia, Jerusalem artichoke, dandelion, chicory, colchicum, many mosses and lichens, etc., and may be prepared by boiling the roots, or in the case of the mosses, the plants themselves, with a dilute solution of sodium carbonate, and cooling the resultant liquid in a freezing mixture. The starch from Iceland moss—lichenin—is easily soluble in water and is precipitated by alcohol.

Starch is one of the first products of assimilation in green plants, being formed from water and carbon dioxide under the influence of light ; and when so formed in a plant it is mainly deposited in the seeds or root, where it serves as a store of nourishment for the young shoots. When required as a nutriment for the plant itself it is made soluble by the agency of particular natural ferments, or enzymes, which convert it into sugars. This starch is utilized as plant food both when the seeds are germinating or the tubers are sprouting, and also (but at a much slower rate) previously to germination and during storage.

Starch is found under varying conditions in different parts of the plant. Towards evening it is usually present in greater amount in the green leaves than in the morning, whilst at night-time it disappears almost completely from them. The proportion also differs according to the weather, the time of day, and the season of the year. In the woody portion of trees and shrubs large variations are also found.

There is also very considerable variation in the composition of a plant at different stages of its growth. For instance, the analysis of the Giant, or Mammoth Russian, Sunflower cut for Silage: (1) before the plants were in bloom, and (2) after the seeds were fully formed, gave the following results—

| Dry matter. | Water. | Crude Protein. | Crude Fat. | Carbohydrates | Fibre. | Ash. |
|---|---|---|---|---|---|---|
| (1) 24·33 | 75·67 | 3·43 | 1·24 | 10·17 | 6·22 | 3·27 |
| (2) 47.69 | 52·31 | 5·06 | 2·42 | 24·75 | 10·16 | 5·30 |

The amount (as has been just said) not immediately required is stored up in the plant itself for its future needs, or in the seeds, tubers, etc., in order to give a good start to the succeeding generation, so man takes advantage of this habit and appropriates the supply for his own use.

It is a possible but rather delicate operation to deprive the leaf of a plant, screened from light, of its starchy contents and to observe the presence of starch after placing it in a solution of sugar.

Glycogen, found in the livers of most animals, may be regarded as the counterpart of soluble starch, and as reserve starch-material, elaborated from the carbohydrates consumed as food.

Starch is, chemically, a member of the group of substances known as the carbohydrates, which also includes the sugars, gums, and cellulose. In the earlier days of chemistry the observation that the members of this group, when treated with strong sulphuric acid, were decomposed by the separation of the carbon, gave rise to the opinion that they were compounds of carbon and water. Further, it was noticed that hydrogen and oxygen were usually present in the same proportions as in water ($H_2O$). This now historic name, carbohydrate, is still retained because the substances to which the term had been applied form a natural group with characteristic peculiarities of structure and behaviour.

The various types of sugars—(beet, grape, mannite, glucose, etc.), cellulose, fruit acids (citric, tartaric, malic, etc.), and other groups of plant substances all owe their origin to the various chemical changes which starch undergoes in the living plant.

Two members of the sub-group of carbohydrates, known as the "poly-saccharides," have an importance in Nature not exceeded by any other organic compound—these are starch and cellulose. The other sub-groups consist of the "mono-saccharides," or simple sugars such as grape-sugar and fruit-sugar, and the group of "di-saccharides" as cane-sugar, milk-sugar, and malt-sugar. All the members of these two last-named sub-groups possess properties such as are commonly associated with sugar; a resemblance which is much less marked in the poly-saccharides, for they are mostly tasteless and hardly soluble in water, though some of them swell up in that medium to form "colloidal" solutions.

Starch always occurs in Nature in the form of grains or granules, which appear to be built up in layers around a central core or nucleus. The shape of the grains, however, differs somewhat with the kind of plant. The granules of most starches possess characteristic forms and frequently also distinctive markings, so that an examination by means of a microscope will usually reveal the source. The average size of the grains is also a useful guide.

The action of dilute acids on starch causes the change known as "hydrolysis," producing a series of products which bear a rather bewildering series of names. And though a great amount of investigation has been devoted to these intermediate products, as yet no absolute agreement has been reached on the subject.

The following list may, however, be taken as sufficiently comprehensive for our purpose—the names are given in the order of formation: Starch, amylo-dextrins, erythro-dextrins, achroo-dextrins, maltose, dextrose.

The number of intermediate products has been notably increased by a few workers, but it is highly probable that some names do not stand for distinct chemical individuals, but rather for complexes of starch molecules in varying degrees of disintegration. "So difficult and complex is the subject of starch hydrolysis that it is predicted that chemists will not be united on it even on the bi-centenary in A.D. 2014 of Kirchoff's observation. Kirchoff was the first to observe the production of crystallizable sugar, from starch. In almost all cases several reactions are proceeding at the same time." (Brown.)

It may be mentioned here that one of the most sensitive and characteristic chemical reactions of starch is the production of a magnificent blue colouration when treated with a solution of iodine. The combination, whether physical or chemical, is of a rather loose character, since the colour is entirely removed on heating to near the boiling point, but returns on cooling; and the intermediate products named above are mainly distinguished by the tint obtained, or, in some cases, the absence of colour, when tested with iodine.

Many ferments, like those present in saliva (ptyalin), pancreatic juice, and especially the diastase of malt, produce a somewhat similar change to that effected by acids.

Certain of these ferments, or "enzymes," exert a most powerful action on gelatinized, as well as on many varieties of raw, starch. The first visible result of this enzyme action is the complete liquefaction, usually in a very short time, a few minutes only in the case of malt extract. Starch paste, for example, which has been prepared for decorators and paper-hangers, under the influence of the enzyme of saliva, is frequently rendered useless in a few hours without the true cause being suspected.

In the case of the action of diastase, conversion probably proceeds in two stages, and it is likely that more than one variety of active agent is present in the malt. The first stage, which causes liquefaction of the starch and stops at the dextrin condition, is due to "amylase"; in the second stage another ferment, "dextrinase," changes the dextrin into maltose. A third stage may be due to the action of "glucase," to which is attributed the power of changing maltose into glucose.

Bacteria grow freely on most starch pastes, but some undergo decomposition from their presence more readily than others. It is on record (Villiers) that a 5 per cent starch paste was completely liquefied by *bacterium amylobacter* in twenty-four hours, the product being dextrins. Under the action of *bacterium butylicus*, or *bact. subtilis*, up to about 35 per cent of butyric acid and 10 per cent of acetic acid is produced, together with smaller amounts of other organic acids. To this fact we owe the unusually disagreeable odour of fermenting starch. Other organisms render starch capable of being converted into dextrin.

Industrially, the hydrolysis of starch is carried out with two objects in view. The first is the preparation of alcohol from grain. After steeping, malt is added to the grain to convert the starch into maltose, which may then be transformed into alcohol by yeast. The other type of hydrolysis consists in the conversion of starch by acids into commercial glucose and dextrin.

Starch is regarded by most workers in this branch of chemistry as consisting of two distinct but very similar substances to which the names amylose, or granulose, on the one hand and amylopectin, or starch cellulose, on the other, have been given.

The amylose constitutes 80–90 per cent of the starch grains, and is converted into maltose (malt sugar) by the action of diastase; the amylopectin being liquefied, but not converted into sugar. Similarly, it is held by some writers that the amylose produces a solution but not a jelly, the other component being responsible for this feature. Amylose represents the soluble form of starch and, when dried to a fine powder, is soluble in cold water. It gives a clear blue with iodine, amylopectin showing a violet tint with this reagent. Indeed, according to Maquenne and Roux, the grain of starch is a species of solution of amylose thickened with amylopectin.

When the layer of amylopectin is quite intact, the starch granules are not affected by cold water, but if ruptured by grinding, water is rapidly absorbed and a small amount of matter passes into solution. By repeated washings the cell-contents may be removed, the outer coating remaining behind as an extremely thin skin of starch cellulose. Starch is also insoluble in alcohol, ether, or similar solvents.

A readier method of separating the components of starch is to treat a starch-paste with diastase or cold extract of malt. This reaction only requires a few minutes, and the cellulose may be separated by filtration. The amylopectin obtained in this way is not acted upon by water heated to 185° F., but boiling water converts a part of it into partially soluble starch, but it does not become entirely so, even after prolonged boiling. A dilute caustic soda or a potash solution will dissolve the amylopectin entirely, and by acidifying the solution with acetic acid it is precipitated, provided, however, that the alkaline solution has not been boiled. When heated with water to about 50° C. (122° F.) the granules of starch show signs of bursting, but all are not ruptured until the temperature reaches about 70° C. (158° F.) when the whole forms a thick viscous liquid which sets to a jelly on cooling, or a gummy mass when dried.

The temperatures at which starches of different origin form the familiar jelly-like pastes are given on page 15. The younger granules show signs of bursting first, the older earlier-formed granules being the last to change.

Other investigators have published results differing from them, e.g. for wheat-starch 80° C. (176° F.), rice of C. (179° F.), maize 75° C. (167° F.), potato 65° C. (149° F.), but probably they refer to starches in very crude and impure states.

| Origin of Starch. | Rupture Clearly Marked. | Gelatinizing. | Complete Gelatinizing. |
|---|---|---|---|
| | Degree Cent. | Degree Cent. | Degree Cent. |
| Rye | 45 | 50 | 55 |
| Maize | 50 | 55 | 62·5 |
| Chestnut | 52 | 56·25 | 57·75 |
| Barley | 37 | 57·5 | 62·5 |
| Horse chestnut | 52·5 | 58·75 | 62·5 |
| Potato | 46·25 | 58·75 | 62·5 |
| Rice | 53·75 | 58·75 | 61·25 |
| Arum maculatum | 50 | 58·75 | 62·5 |
| Tapioca | 50 | 62·5 | 68·75 |
| Arum esculentum | 45 | 63·75 | 68·75 |
| Wheat | 50 | 65 | 67 |
| Maranta arundinacea | 66·25 | 66·25 | 70 |
| Sago | 66·25 | 66·25 | 70 |
| Buckwheat | 55 | 68·75 | 71·20 |
| Acorn | 57·5 | 77·5 | 87·55 |

When examined under a microscope of sufficient power, the granules appear to be made up of a series of layers. The outer layer is the oldest in point of growth, each interior layer being younger and less compact than the one immediately surrounding it.

Starch paste, if prepared from highly purified material, remains unchanged for a long period in air which is free from dust; ordinary, i.e. not specially purified, starch frequently becomes sour in a short time. This sourness is due, in the first instance, to the formation of lactic acid, followed at a later stage by acetic and butyric acids, as a result of the action of certain ferments.

The outer walls of the starch granules may be dissolved by other chemical substances besides caustic soda or potash, the action of zinc chloride being of some interest.

Starch forms a definite compound with soda or potash (but not with ammonia). When these alkalis are added to starch paste, the amylopectin is dissolved and the liquid becomes transparent, and remains so even after the neutralization of the alkali by acid.

The semi-transparent starch paste made by boiling starch with water is not a true solution, as may be shown by the fact that it may be frozen out of the water. For the purpose of preparing starch in a pure condition, a 1 per cent suspension of starch in water is frozen, causing most of the impurities to pass into solution.

By prolonged boiling with water starch passes into solution, one part dissolving in fifty parts of water. The same or a similar change may be effected more quickly by heating to a higher temperature; at 150° C. under pressure the change is rapid.

Another, or perhaps identical, form of soluble starch may be prepared in various other ways, such as by the action of hydrochloric acid or malt extract. When made thus it is only slightly soluble in cold-water but readily dissolves at 60–70° C. The manufacture of soluble starch is dealt with in another section. (*See* p. 88.)

When starch is heated to the boiling point with very dilute acids, practically no starch paste is formed, the substance being transformed into soluble starch, dextrins, and maltose. When acted upon in the cold by most acids (not acetic or oxalic acids) an immediate swelling of the granules occurs.

As usually met with in ordinary life, starch is a brilliant, tasteless, inodorous white powder. Commercial starch contains about 18 per cent of moisture which can be removed by very careful heating in a current of dry air at about 105° C.; and thus dried, it rapidly regains the water it lost on exposure to ordinary air and, in a moist atmosphere, may absorb as much as 35 per cent of moisture.

When perfectly dry, starch may be heated to about 160°·C. with little or no change in appearance, but at higher temperatures it becomes yellowish in colour; but ordinary starch, i.e. that which contains moisture, is rapidly altered at the temperature mentioned. Starch, it should be noted, is about one and a half times heavier than water (Sp. Gr. 1·505).

Although starch is one of the most widely diffused substances in organic nature, occurring more or less abundantly in every plant that has been examined, the number of commercially important raw materials for its manufacture on a large scale is not large. It is, however, found in great abundance in the seeds of all cereals as well as in those of leguminous plants (beans, peas, etc.), in the stems of various species of sagus and cycas, in the roots of many plants mainly of the *euphorbiaceae* and *zingiberaceae*, and in the tubers of potato, canna, and manioc. Since many of these are also food-stuffs of great importance, it is self-evident that their industrial uses cannot take the place of the food requirements of mankind, which must be considered first of everything in importance.

Among the commercial products of the world vegetables are a most important item, and their value as a food-stuff needs no emphasizing. The inhabitants of the world could subsist without animal flesh, with some difficulty they might subsist mainly on cereals, but most certainly they could not live without vegetables. Practically every nation, primitive and civilized alike, cultivates a few plants as vegetables. It is, therefore, high time that some organization was set up to maintain on a permanent basis, a survey of the food resources of the nation, as initiated by the Food (War) Committee of the Royal Society, but unfortunately work of this kind does not appear to be anybody's business.

The name starch is commonly applied to the material obtained from all sources, but the origin is sometimes indicated by prefixing the name of the plant from which it is usually prepared, e.g. potato starch, rice starch, etc., sometimes the word starch is omitted, as in sago, arrowroot, tapioca.

The following table will give the approximate amount present in some of the more important raw materials used for starch manufacture—

| | | | |
|---|---|---|---|
| Potato | . 18–20 | per cent. | |
| Wheat | . 53–60 | ,, | |
| Rice | . 50–75 | ,, | |
| Maize | . 55–65 | ,, | |
| Manioc | . 25–40 | ,, | (Dried root, 75–85) |

In the manufacture of starch the separation of the non-starchy portion of the plant is effected mainly by mechanical means; the treatment in outline consisting in tearing open the plant-cells by crushing and disintegrating, and then washing out the starch with water. By the careful sieving out of impurities and allowing the milky starch-water to settle, starches of varying degrees of purity are obtained. Mechanical methods suffice in the case of the potato, but more complicated modes of procedure are necessary when dealing with wheat or rice. The raw materials, so far as Europe is concerned, are potato, wheat, maize, and rice, and the selection is based, in addition to locality, on (1) crop-yield per acre, (2) yield of starch per acre, (3) starch content.

We have noted that wheat contains 53–60 per cent of starch and potato only about 18 per cent, but the yield per acre is in favour of the latter. The usual

English potatoes contain only about 13 per cent but some German varieties, by prolonged selection, contain about 18–24 per cent, or even in very special cases 28 per cent.

It may also be remarked here that diseased or over-ripe grain or tubers contain far less starch than sound material, and that in cold seasons the yield is also diminished.

# CHAPTER III

## POTATO STARCH

THE potato is still found in a wild state in Chili, in a form very similar to the well-known garden plant. Its cultivation seems to have been diffused from that country to New Granada long before the discovery of America, and to have spread to the newly colonized districts, now known as Virginia and North Carolina, towards the latter half of the sixteenth century. From the New World it was first imported by the Spaniards into Europe, and reached England *circa* 1580–85, at the time of Raleigh's voyages to Virginia.

This valuable tuber, therefore, reached Europe towards the close of the sixteenth century, and a striking indication of the interest attached to the novelty is found in *Gerarde's Herbal*, published in 1597. For Gerarde, in presenting his own portrait, elected to hold in his hand the flowering branch of a potato plant, which he had cultivated in his own garden. (Frontispiece.)

In the time of James I potatoes cost two shillings per pound, and are mentioned amongst the articles provided for the royal household in 1619.

Farina, as the starch from the potato is usually named, is extensively produced in Germany and Holland, the imports, previous to 1914, of this substance into England being about 38 per cent from Germany; 25 per cent from Holland; and 25 per cent from America.

The Dutch potatoes are mainly grown in the *Veencolonien*, or turf colonies, of Groningen and Drenthe.

The size and quality of the potato crops are generally known about the middle of October, and the manufacture of farina is then in full progress so that it may be transported to the ports before the close of inland navigation.

In appearance farina is a glistening white powder which gives a semi-transparent characteristic paste. With the exception of maize, farina gives a thicker paste than other starches. Thin paste or size made from farina must not, however, be subjected to a prolonged boiling, as by so doing it quickly loses its adhesive properties. Caustic soda is used as a preventive of decomposition, and to counteract the thinning of the size and so to maintain its "strength."

Farina is much used for light sizing, and in conjunction with other starches for heavier sizing of textile goods. It is also employed for the filling of the opaque and white soft soaps, made on the Continent, especially the German "silver soap."

The tubers may contain as much as 80 per cent of water and is rarely less than 70 per cent. Those with the lower water content give "mealy" potatoes when cooked, those with more water are less readily crushed.

The mineral constituent most abundant in the potato is potassium phosphate, and it is unfortunate that in the usual method of cooking—quite indefensible from a chemical standpoint—the valuable salts of the root are lost.

The starch manufacturer will naturally select the variety of potato which contains most starch, provided that other qualities, such as thin skins and good shape, are present.

The grower of the potatoes must, therefore, on his part, pay attention to the time of ripening, resistance to disease and adverse climate or soil, and to good keeping properties.

A poisonous substance, known as solanin, occurs amongst the nitrogenous contents of the potato, but is exceedingly small in well-ripened tubers. The "crude fibre" does not usually exceed 1 per cent, and is derived from the cell-walls and outer skins, but a high fibre content is detrimental.

It is important to the starch-maker to be able to estimate the probable quantity of finished starch obtainable from a batch of raw potatoes. The sampling of the bulk must be done with considerable care, or the figures obtained will be too uncertain to afford good control of the whole process. The chemical methods of determining this starch-content are rather complicated and require some time to perform, also they cannot be done by an unskilled person. To get over the difficulties of the chemical methods a far simpler way has been worked out, depending merely on the specific gravity of the potatoes. The data obtained by such methods are far from absolute values, but are, if the weighings are carried out under identical conditions, relatively useful.

The volume of water displaced by submerging a known weight of potatoes, or the difference in weight of a fairly large bulk of potatoes when weighed in air and in water are compared. A variety of weighing contrivances have been devised to make the whole estimation simple and as free from error as possible; so that, by reference to a table calculated for the purpose, the starch content can be determined with ease and rapidity.

One type takes the form of an enlarged "hydrometer." A known weight of tubers, say 10 lb., is introduced into a wire basket suspended below the spindle. The whole is floated in a vessel of water and the starch content is read off from marks on the spindle.

In all cases it is absolutely necessary that the tubers are freed by washing from all adherent soil; an allowance, however, for the water retained being possible, the necessity of drying before weighing may be thus avoided.

Usually the potatoes cannot be worked up for starch directly they arrive from the field, and the storage requires much care or considerable loss of starch may occur. Since the life-process does not cease after removal from the soil, if the temperature is suitable, the formation of sugar may intervene and a corresponding loss of starch, amounting to as much as 40 per cent or more in half a year, may be caused. The total loss of weight of potatoes during storage is due to a number of causes. There is, for instance, the loss due to evaporation of water, as well as that caused by chemical changes. The chief of these changes are probably (*a*) formation of sugar from starch; (*b*) the production of carbon dioxide and water as a result of "breathing"; (*c*) the re-formation of starch from the sugar. At temperatures near the freezing point (*a*) is still active but (*b*) much reduced, resulting in a marked sweetening in the taste. When the temperature rises (*b*) is speeded up and the sugar consumed. The third change (*c*) is not very much in evidence.

The range of temperature in the store should not pass the limits 32°–45° F. The "sweating" of potatoes in the heaps is due to the heat produced by the "breathing" of the tubers, and unless care is taken, may result in great loss through the growth of moulds. In case of heating the "tump," or "hog," should be opened and re-made.

The mould, which is chiefly responsible for the decay of potatoes, is the *phytophthora infestans* which converts the pulp into a soft slimy mass from which starch cannot be separated. A very small number of infected tubers may cause the destruction of the whole heap in a few weeks.

The "skin spot" disease in which the tubers become dotted with small dark spots during storage is due to a mould known as *oospora pustilans.* This brings disfigurement, and almost certainly also serious injury to the tubers.

The first treatment of the potato, preparatory to the extraction of the starch, is to thoroughly clean the tubers from all dirt and stones. The amount of the adhering soil and the admixed stones is variable but may amount to 20 per cent of the total weight. The usual form of washing machine is a revolving lattice-work drum which is slightly inclined in order to assist in the forward movement of the contents.

In some large works a softening of the adhering clay and preliminary rough washing is combined with the transport of the potatoes, by means of troughs through which a stream of water is flowing.

Many other types of more elaborate construction are also in use, the chief aim being to avoid hand labour as much as possible and the use of excessive quantities of water.

From the washing drum the cleansed material passes on to a contrivance designed to remove any stones which may have been too large to pass between the bars of the drum. This "stone catcher" is an inclined trough through which passes a shaft, carrying spirally placed arms. The rotation of the shaft and the action of the arms causes the tubers to rub upon one another and to be repeatedly plunged into the water in the trough. The arrangement of the arms carries the tubers to the upper end of the trough and empties them either directly into the rasping machine or on to a band-conveyor. In some factories the treatment in the stone-catcher precedes the washing in the drum, and the two machines are assembled into *a single one with* two separate compartments.

The moving parts of all these are constructed in such a manner as to avoid any crushing or cutting of the potatoes.

The cleaned tubers are now rasped to a fine pulp in machines specially designed to tear open the cells and set the contents free. It is obvious that inefficient action will allow much of the starch to remain within the cell, and if the granules are themselves much reduced by grinding, loss will follow in the subsequent operations. Therefore, it is sometimes advisable to perform the rasping in two stages, millstones being used for the second stage.

A form of rasper which is frequently employed, consists of a casing within which a hollow cylinder, provided with saw-blades on the inner surface, can be rotated at a speed of about 1,000 revolutions per minute. The potatoes are pressed against the blades by a single block, or pair of blocks of wood or metal, which can be adjusted by screws. Water is forced in and carries the pulp through the narrow spaces between the blades into a receiver beneath the machine. The blades require frequent sharpening and renewal, and the arrangement of the drum allows this to be easily done. In some types the whole drum can be replaced by a new one, and loss of output during the re-setting of the blades be thus avoided.

Large machines are capable of pulping about 12 tons of potatoes per day. The efficiency of starch extraction is very important, as the starch left in the pulp has a much lower monetary value in the form of cattle-food than as a finished starch powder.

The yield, though dependent on the efficient working of a series of machines, is affected most of all by the losses incurred through bad working of the rasping machines.

Therefore, the installation of a second rasping machine, to deal with the residual pulp left after extraction of once-treated material, is often unavoidable. These second-stage rasping machines are usually similar in design to the first-duty machines, but furnished with three or more blocks to press the material against the blades, and the latter may, with advantage, be provided with finer teeth.

The chief difficulties are due to the necessity of opening the cells to free the starch granules so that the stream of water washes them out and of avoiding the grinding of the starch or accompanying fibre. Any particles of fibre of small size pass forward with the starch and may introduce complications in later operations.

In another type of rasping machine the pulp is partly freed from water by a worm working in a perforated compartment, and is forced against a high-speed grating drum. This form is readily adaptable as a second-duty machining after the first separation of starch and requires less power than millstones. The machines copied from the domestic graters, are now but seldom used, for the product is not sufficiently fine and the cost of renewals of the perforated graters is very high. The differences in character of the pulp coming from the rasping machines arise from variations in the fluid content of the potatoes, but this can, to some extent, be met by adjustment of the amount of water used.

The fluid from the machines consists mainly of the torn cells and their contents, both liquid and solid, as well as portions of the outer skin of the potato and undamaged cells.

The next operations have for their object the complete separation of the starch from the other components.

This separation of the granules is entirely mechanical. Jets of water are directed on to the pulp which lies on sieves of the requisite fineness. The process is assisted by brushes.

The old hand-methods which demanded much labour and time, have now been superseded by mechanically-driven machines (Fig. 1). Sieves are mounted in such a way that a rapid shaking motion can be given to them, and jets of water from above the sieves wash out the

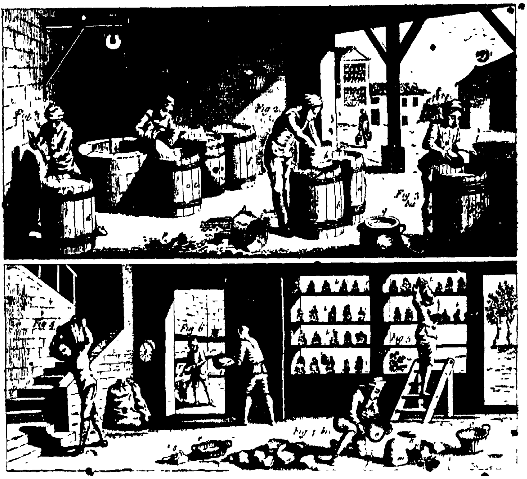

FIG. 1

REPRESENTATION OF ALL THE NECESSARY OPERATIONS IN THE MANUFACTURE OF STARCH granules which pass along the trough fixed beneath. This form of apparatus is usually employed to separate the starch from the first-stage rasping machine, the residue retained by the sieves being further disintegrated in the second-stage rasper. Many other types of sieving machines are in use, the principle being the same in all cases.

The sieves may be horizontal and stationary and the brushes rotated, or, as is probably more frequent, they may be of cylindrical form with rotating brushes inside, or finally the sieve-cylinder may itself be rotated (Fig. 2). A good deal of floor-space is saved by assembling the shaking-sieves and cylinders in a combined machine. The material is treated in the shaking sieves, which deliver the starch to a cylindrical sieve below for further separation.

The milky liquid from the sieves will deposit the suspended solids on standing, for the starch settles fairly rapidly while the liquid cell-contents remain in the water. In warm weather the liquid readily decomposes and consequently must be removed as rapidly as possible.

The starch in the pale brown deposit undergoes various processes of purification, based on the physical and chemical differences of the constituents of the mixture. The specific gravity of starch is greater than that of the unopened cells or the skin of the tubers and so settles out more rapidly, also the starch granules are more resistant to chemical change.

The settling of the starch can be accomplished in vessels provided with means, such as an adjustable pipe, to remove the wash water from the sediment of starch without disturbing the latter. The same result may be achieved by allowing the starch liquid to flow along a series of troughs in which the solids are deposited in

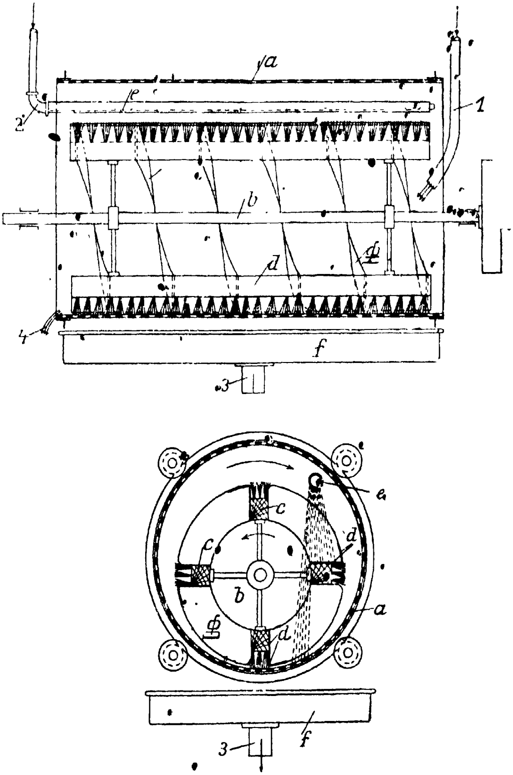

FIG 2

*a* . Rotating cylinder
*b* .... Shaft
*c* . . Brushes
*d* ... Scoops or paddles
*e* . .. Water spray
*f* .... Collecting trough

the order of their specific gravities." The trough method requires a good deal of ground space, but the necessary labour is much less than that needed in the other method. Centrifugal machines are also used, the heavier starch collecting on the walls of the rapidly revolving drum, the water and the lighter particles passing off nearer the centre.

Further purification is effected by stirring up the starch with more water and settling a second or third time, and finally washing away the impurities, which have settled on the upper surface, with water sprays. These final washings are carried out similarly to the first; or washing vessels, provided with special devices for collecting separately the upper surface starch, may be employed. The upper layers are then re-washed.

Chemical treatment may be necessary to assist rapid settlement, to prevent fermentation, or to improve the whiteness of the starch. Raw starch settled from the pulp contains various impurities such as cellulose, albumenoids, fragments of potato, etc. To hasten the separation of the re-washed starch, small quantities of alum or sulphuric acid may be used. The alum, however, has the disadvantage of coagulating the albumen and to that extent contaminating the starch, the sulphuric acid has a slight chemical action on the starch itself and is also difficult to remove.

When the tubers are more or less affected by disease or frost, great difficulty is experienced in securing a speedy and complete precipitation of the starch, and various re-agents such as calcium bi-sulphite, sulphurous acid, or caustic soda solution may be called into use.

The potatoes used for starch manufacture, ***Fabrikkartoffeln***, contain on an average about 18 per cent of starch and, with good working, this will produce about 14½ per cent of commercial farina of "prima" or superior quality and $2\frac{1}{2}$ per cent of inferior *schlammstaerke.* Good samples of farina should be free from specks (*stippen*) and not contain any acid.

If the starch, now containing about 50 per cent of water, is to be worked up into syrup, etc., nothing further is required, but for other purposes the water content must be reduced by drying to about 20 per cent. Since the water in the raw substance cannot be removed by pressing, and air-drying is a very slow process, the starch is liable to become impure through exposure to dust and in very great danger of fermentation. Owing also to the ease with which the wet starch gives a pasty mass with water, only low temperatures can be used to hasten this removal of water. By the use of centrifugal machines the water can be reduced to about 40 per cent, and from this stage artificial warmth can be employed with less danger of damage. The drying chambers are so designed that a current of warm air at 20°–30° C. passes through them, and the moisture-laden air escapes by shafts at the top, or is exhausted by suction fans. But great care is necessary in order to maintain the correct temperatures and to secure continuous and complete drying. The drying process usually requires about two days but is naturally dependent on the original moisture present in the starch, physical condition, and other factors. The drying of starch may be also satisfactorily carried out in tunnel dryers. In these the starch is mechanically carried forward at such a speed that it is delivered at the outlet in a dry condition.

Another type is constructed with a series of endless bands between which are steam coils, and by such means the duration of the drying operation is much shortened, and the ground area occupied by the apparatus is lessened. The risk of gelatinizing the starch is also minimized, and other advantages are achieved by employing a vacuum drying machine. The low pressure causes the moisture to be given off at a temperature below that at which gelatinization takes place, and the moisture can be reduced to a figure much below that of ordinary commercial starch (about 20 per cent) or even to complete dryness.

The temperature of the drying chambers is insufficient to remove the whole of the water from starch, this requiring a temperature of about 110° C. Dry starch readily re-absorbs moisture and soon regains about 20 per cent. If the product is required in lump form, drying chambers give the best result, but if in powder form the other types are preferably used.

Starch factories necessitate enormous supplies of water, amounting to $1\frac{1}{2}$–$2\frac{3}{4}$ cubic ft. for every hundredweight of potatoes. The disposal of all this waste wash-water requires many acres of land for disposal purposes, varying from about 5 acres for small factories to 85 acres for large establishments

# CHAPTER IV

## CEREAL STARCHES

In the temperate regions of the world wheat is the principal cereal, but as we go farther northwards barley, oats, and rye increase in importance. For these cereals will thrive under conditions not suited to wheat.

Starting again from the temperate zones and travelling gradually southwards (or in the southern hemisphere northwards), we pass through the warmer countries where the cultivation of wheat is usually associated with that of rice, maize, sorghum, etc. Further south, in the tropics, true wheat will not thrive at low elevations, and the above-mentioned grains with the various millets form the great cereal crops. Sometimes, however, this word "cereal" is extended to include buckwheat and other starch-yielding plants, though they are not true cereals.

The three chief groups of "wheat" are—

(1) Small-spelt (*Triticum monococcum*).
(2) Wheat-spelt and rice-spelt (*Trit. sativum*).
(3) Polish wheat (*Trit. polonicum*).

The first of these has practically gone out of cultivation in most countries since the yield is small in comparison with that of the second group, but as it is very hardy and produces fair crops, even in very poor soils and in stony places, it is still to be found growing in southern Spain, and, to a lesser extent, in the mountainous districts of France, Germany, and Switzerland. Grains of the smaller spelt have been found in the Lake Dwellings of the Stone Age, a proof of its great antiquity. And though this form is not extensively cultivated at the present time, it was in former days the chief cereal of Egypt and Greece, and was distributed by the Romans throughout their whole empire. It may prove of great use even now in certain dry regions of North America where irrigation is impracticable.

All the other groups of "wheat" are descended from this "small spelt" group. As we have remarked above, pile-building Neolithic man cultivated his corn in this shape, and certain authorities have put the date of the first harvest fields at between 10,000 and 15,000 years ago. "The ancient civilizations of Babylon, Egypt, Crete, Greece and Rome were largely founded on wheat, and it is highly probable that the first great wheat-fields were in the fertile land between the Tigris and the Euphrates. The oldest Egyptian tombs that contain wheat (which, by the way, never germinates after its millenia of rest) belong to the First Dynasty, and are about 6,000 years old." But there must have been a long history of wheat-cultivation before that. For wheat is not a natural crop; it demands careful attention. If a field of wheat is left to sow itself, as in an experiment at Rothamsted, every single plant will vanish after three years And when harvested, the grain will not keep its vitality for very long, its power of germination dwindling rapidly, and disappearing altogether in fifteen years

It is also a very interesting fact that the almost certain ancestor of all our ordinary wheats is at present living on the arid and rocky slopes of Mount Hermon, where it was found in 1855, and re-discovered in 1906. It is called *Triticum hermonis*, and is varying notably to-day, as it did long ago when it gave rise to the emmer, or spelt, of the Newer Stone age Observant individuals would notice odd ears with bigger grains or looser chaff, and from them raise a richer harvest for their tribe. So, in the course of time, "man took advantage of the numerous varieties that cropped up in this 'sporting' stock, and established one successful race after another in his fields. Virgil refers in the Georgics to the gathering of the largest and fullest ears of wheat in order to get good seed for another sowing, but it was not until the first quarter of the nineteenth century that the first great step was taken by men like Patrick Sheriff, of Haddington, of deliberately selecting individual ears of great excellence and segregating their progeny from mingling with mediocre stock. This is the method which has been followed with remarkable success in modern times. The Marquis wheat, one of the factors that assisted the Allies in overcoming the food crisis in the darkest period of the war, originated from a single grain planted in an experimental plot at Ottawa, by Dr. Charles E. Saunders in 1903. Three hundred million bushels of this wheat were raised in North America in 1918."[1]

In England the name given to the wheat plant is connected with its white colour, being derived from the Anglo-Saxon *hwaete*, or *hwit*, meaning "white." But in Ireland its name signified "blood-coloured," the Irish wheat (now rapidly becoming extinct) being "distinguished by its red or sanguine hue." It is this fact which supplied so dramatic a touch to the description, given by a poet of the time (A.D. 651), of the death of two Irish princes in Mailoran's mill (*cf.* W. W. Skeat, *The Past at Our Doors*).

There is an immense number of types of the second of the above groups of plants, characterized by the presence or absence of a beard or "awn," long or short straw, hardness or softness, colour of the grain, etc. True "wheats" may be sub-divided into four or more main classes, each of which contains many varieties, flourishing best under fixed conditions of soil and climate. The "hard" or "flint" wheats contain a large amount of gluten, and consequently are of special interest as yielding the best flour for macaroni and Italian pastes.

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[1] See *Outlines of Science*, J. A. Thomson; *The Wheat Plant*, John Percival; *Essays on Wheat*, Buller.

Polish wheat—the third group—grows into a large plant but gives only a small yield of grain. It is, however, much cultivated in northern Spain where it may have originated.

It may be remarked here that the wheat-lands of the Argentine, gently sloping to the Parana and other rivers, are capable, under good cultivation, of producing enough wheat for the whole human race. The rivers also are open for 1,500 miles inland for vessels capable of carrying 800 tons.

The preparation of starch from wheat requires a series of operations which differ from those employed when potatoes form the raw material. Unlike potatoes, which consist mainly of starch and water, wheat, barley and the like contain within a hard outer covering the nitrogenous substance known as gluten (about 14 per cent) in addition to the starch, while the water content is usually about 12 per cent.

The microscopic appearance of wheat-starch granules is quite unlike those in the potato, being more circular and much smaller. Wheat starch also does not normally contain more than half the amount of water present in potato starch.

The temperature at which the granules burst to form a paste is also considerably higher.

The extraction of starch from grain is effected in two ways: (*a*) the older method of fermentation, involving the loss of most of the other constituents, and (*b*) the "washing out" process. Both, however, aim at complete separation of the gluten from the starch. The physical and chemical properties of the gluten introduce very considerable difficulties. From an economic standpoint the loss of the gluten, or its recovery in low grade quality suitable only (*a*) as a fertilizer, or (*b*) as an adjunct to pig-meals, is not sound and consequently the fermentation process is giving place to the more rational type in which the starch is not considered the sole product of importance.

The first stage of the work consists in the soaking of the grain in water until swelling has taken place. The whole grain is frequently subjected directly to the steeping process, but this is slow as the outer husk prevents the easy passage of the water. To obviate this the grain may be crushed, but grinding must be avoided.

In small factories tubs may be used, but in big works large concrete tanks are more suitable. Repeated treatments with water are necessary, and the operation may require a week to carry through to completion. The temperature of the water is also important as the grain will require a much longer time if this is very cold. A sample taken from the bulk should only give soft grains which can be bent without fracture and which show no unswollen portion when divided.

The softened grain is next passed through a roller mill and thoroughly crushed, forming a somewhat pasty mass which is, in the third stage, delivered into the fermentation vats, situated usually immediately below the mill. These vats are similar in structure to the soaking vessels.

The regulation of the temperature requires very careful attention as otherwise the fermentation will not be uniform. The mass from the crushing rollers is mixed with water to a thick " soup " in which a rod can be moved without great effort. A very considerable increase in volume accompanies the fermentation and this must be taken into consideration in designing the vats.

The gaseous products are evil-smelling, and, in most cases, it is necessary to conduct these away to the boiler fire-box or other furnace. The onset of the fermentation is usually quickened by the addition of some of the liquid in a more advanced stage of decomposition, or beer-yeast or other fermenting liquor.

At 25°–30° C. the action is very brisk and will require less than a week to complete, but at 14°–18° C., probably about ten days. The smell is alcohol at first but rapidly passes through a sour stage to that of rancid butter or old cheese, and eventually to an exceedingly disagreeable odour.

The whole process is a complicated one, in which the acids produced (acetic, lactic, etc.) have a solvent action on the gluten and, combined with the decomposition of the gluten itself, effect the separation from the starch. The process must be arrested before the whole mass becomes slimy as this would interfere seriously with the washings which follow.

These washings of the fermented mass are far less simple than in the case of potato pulp. A preliminary separation of the sour liquid from the mass may be carried out on sieves, but the main washing is done in perforated drums, furnished with water sprays.

Owing to the rapid corrosion of metal by the organic acids present, wooden drums or wooden frames covered with canvas are preferable. The water is with advantage introduced under some pressure through the hollow axle, perforated for this purpose. The starch contained in the milky liquid is refined by repeated settling and washing with water in a similar manner to that already described in the previous chapter. (*See* p. 30.) The washing process is a tedious one as the gluten adheres obstinately to the starch, and the upper layers of the latter, which are of a brownish tinge, must be removed for further treatment. The centrifugal machines used for wheaten starch differ from those already described, for the basket is not perforated and the action is based on separation according to density.

The partially purified starch is introduced into the machine as a thick milk, and after "centrifuging" until the liquid in the centre is clear, the machine is stopped as rapidly as possible and the liquid contents removed by opening a valve at the bottom of the basket. The pure starch, owing to its greater density, will be found in the layer next to the walls, and the less pure nearer the centre. By scraping away the lower grades, the higher grade starch is collected separately. The water content can be reduced to about 50 per cent by the ordinary design of hydro-extractors. The drying can also follow the same procedure as with potato starch.

In the case of starch separated by settlement, the method of handling is often modified, and especially is this the case when air-drying is adopted. The cake of starch-mud at the bottom of the vessel, after running off as much water as possible, is too sloppy to be handled conveniently. Advantage is therefore taken of the great absorbing power of dried starch to remove water from wet, low grade products and sweepings being employed. The surface of the wet starch is covered with a coarse cloth and the dry residuals placed above to a depth of a few inches. The upper layer in the course of several hours will have absorbed so much water from the lower layer that the latter can be readily removed by a shovel.

*The drying, notably in the case of wheat and rice products, must be carried out sufficiently rapidly to avoid the growth of moulds.* These attack not only the gluten which may be present, but also the starch itself, and consequently a serious loss of output may occur. The cost of fuel for hot-air drying is, however, fairly high and, therefore, all methods which lessen these changes are desirable.

Advantage also may be taken of the absorbing power of gypsum by spreading the wet starch on blocks of this material, and the drying completed by exposure to the air during periods of warm weather. The cone-shaped masses are placed on floors or shelves, provision being made for a good circulation of air through the drying rooms. Two months may be required to dry the starch, the product is then known as "hurdle" starch. The great drawback is the possible contamination by moulds and dust, which will necessitate the removal of the exposed portions. Suction filters may take the place of the hydro-extractors already mentioned.

The characteristic irregular shapes of laundry starch are controlled by the speed of drying and cannot be produced in mechanical drying. Rapid drying and high temperatures yield short and thin sticks, the lower the temperature the thicker the rods or prisms. The coherence of the granules to form prisms is due to the presence of small amounts of gluten or, in the case of very white material, by the addition of dextrin to the gluten-free starch, followed by slow drying in paper wrappers.

The removal of the last traces of gluten may be effected by a final washing with very dilute ammonia.

The growth of moulds may be prevented by the addition of disinfectants, such as phenol, but these must be excluded where the products are to be used as food; there is also a considerable risk of the disinfectants finding their way into the fermentation vats and, exercising their antiseptic action in a manner not desired, preventing the working up of residuals and sweepings.

Starch of slightly lower grade than the whitest and still containing some gluten, forms a very good paste, in fact, better than that from the first quality. It is much used in the textile, cotton-printing, and similar industries.

The methods of extracting starch from grain by mechanical means, without making use of a fermentation process, will probably in time replace the procedure described above.

The first operation, the swelling of the grain, is similar to that already mentioned, but fermentation is hindered by frequent changes of the steeping water, and temperatures up to about 30° C. are advisable.

When the grain can be easily burst by squeezing, the steeping is complete and the water is drained away from the swollen grain.

The rupture of the grain is achieved by passing it between finely-fluted rollers at such a distance apart that the milky contents are expressed from the husk. The old method of kneading with the feet the dough contained in sacks is now abandoned, but machines have been designed which imitate this somewhat primitive method. A ring-shaped sack of rather flat section is passed between grooved rollers, usually of wood, running in a vat of water.

Since it is possible to combine the washing with the crushing of the swollen grain, a machine with a series of pairs of rollers, placed one above another, and sieves of varying mesh to retain the gluten and husk, is often used. The purification follows much the same lines as in the previous description.

Owing to the very small amount of gluten left in the starch, a very slight fermentation, lasting only a couple of days, is sufficient to remove it, and a few subsequent washings will yield a high grade material.

The extraction of starch from wheat meal, instead of from the crushed grain, is carried out by Martin's process. A stiff dough is first made and a product suitable for further treatment is produced by extruding this through a small die, and cutting the mass into short lengths. The prepared dough is washed on a shaking sieve by fine jets of water. Other machines are provided with a travelling roller to assist the separation. The final traces of gluten may be removed by the addition of a very dilute solution of caustic soda, which causes it to swell, and in this condition it can then be removed by a fine sieve Martin's procesc is reported to yield 50 per cent of starch, while the old process by fermentation yielded 40 per cent.

Beccari seems to have been the first to successfully carry out this separation of starch from flour, which he did in 1745.

The hardness of barley enables it to be cultivated in higher latitudes than any other cereal. Pliny regarded barley as the most ancient foodstuff of mankind.

The number of existing varieties is great, but these can mostly be accommodated in one or other of the following groups—

(1) Common or two-rowed barley (*Hordeum distichum*).
(2) Bigg or Bere (*Hord. vulgare*).
(3) Six-rowed barley (*Hord. hexastichum*).
(4) Fan or battledore barley (*Hord. zeocriton*).
(5) Naked barley (*Hord. celeste,* and *Hord. nudum*).

The nutritive value of barley is considerable, but its comparative poverty of gluten is the chief objection to its suitability for bread-making, and at the present time it is largely used to supply the malt for brewing purposes.

Malting has for its object the production of a ferment or enzyme, known as diastase, which possesses the property of converting starch into sugar. During the germination of the seed the large amount of starch in the grain is transformed into sugar, which in the ordinary course of nature is utilized by the seedling as food.

In the preparation of malt the barley is steeped in water and then allowed to germinate in a favourable temperature until the diastase is fully developed. This diastase is usually at its maximum when the rootlets are about two-thirds of the length of the grain.

The germinated barley when dried is known as malt, and after being coarsely ground in a mill is placed in a vat through which water is forced, the whole mass being carefully stirred to extract the starch and diastase.

In the subsequent infusion process the malt is raised to a temperature of about 140° F. by running hot water into the vat with the result that in a few hours the starch has been converted into sugar by the ferment. The conversion of the sugar into alcohol and carbon dioxide is effected by adding brewers' yeast to the liquid after drawing it off into separate vessels. When the fermentation is completed, the alcohol is obtained by distillation.

The true home of rye (*Secale cereale*) is in the regions around the Black and Caspian seas, and it does not appear to occur in many varieties, in this respect differing from most other cereals.

In Great Britain rye is usually grown, if cultivated at all, as a forage crop, but in Russia it is by far the most common cereal; immense quantities are also raised in Scandinavia and northern Germany, where rye, or "black" bread, is so important an article of food.

Oats (*Avena sativa*) are known from historical record to have been cultivated in very early times in northern Italy and Greece, and this fact disposes of the assertion that its original home was Juan Fernandez. A bristle-pointed oat (*A. strigosa*) is a variety and not an independent species; the same may be the case with *A. orientalis*, known also as the Turkish and Hungarian oat. In a Chinese work covering the period of A.D. 618–907, there is a description of a naked oat (*A. sativa nuda*) which is still found in a wild state around Pekin. This plant may be the "pilcorn" mentioned by agriculturists in the thirteenth century. Oatmeal can be baked into cakes or biscuits, but owing to the difficulty of rupturing the starch grains, except at a high temperature, the meal does not lend itself to bread making.

The constituents of good standard grades of typical cereals are approximately—

| | Protein. | Carbohydrates | Oils and Fats. |
|---|---|---|---|
| Wheat . | 10 | 69 | 2 |
| Rye . . | 10 | 69 | 1 |
| Oats . . | 9 | 47 | 4 |
| Maize . | 8 | 67 | 4 |

# CHAPTER V

## MAIZE AND MILLETS

WHETHER maize (*Zea mays*) owes its origin to the old or new world is still a debatable point. De Candolle held that the evidence of Asiatic origin was not convincing in view of the proofs of its great antiquity in the American continent. For it is well known that when America was first discovered maize was being widely cultivated by the aborigines. It is a true grass, now only known in a cultivated state for the wild source of the plant is still obscure. One theory (that of Collins), which is based on breeding experiments and comparisons with other plants, argues that maize started as a hybrid between the Mexican "teosinte" (*Euclaena*) and some unknown grass of the order *Andropogoneae*, a suggestion supported by recent work of Kuwada, which has independently confirmed it. As also has Mr. Luther Burbank, who, after experiments extending over eighteen years, in 1921 succeeded in producing a new variety of maize by intensive cross- and inter-breeding and careful selection, and planting of suitable seeds of the wild teosinte grass of Mexico and South Florida. This proves that the origin of many known varieties is to be found in the hybridization and mutation of the forms grown by the natives in many parts of the American continent, where it appears to be indigenous. At all events, many varieties have been evolved, some writers stating the number to be 300, which differ mainly in their size, shape, time of growth to maturity, or nutritive value.

Maize often grows to a height of 10 or 12 ft., and bears beautifully-tasselled male flowers, as well as female flowers, which develop into cobs close to the central axils of the leaves (Fig. 3).

Though it can be successfully grown in the South of England as a fodder crop and is very suitable for ensilage, our climate is not really suitable for this cereal, and we purchase large supplies from the Danubian provinces, but our greatest imports are from North America. It has been for a long time cultivated in the East Indies, China, and Turkey, mostly, however, for home consumption, as is the case also in Australia and South Africa (Fig. 4).

The cereal is known under many different names: In Great Britain as Indian corn; in America as corn; in Holland and Hungary as Turkish wheat; in France as Spanish corn; in Turkey as Egyptian corn; in Egypt as Syrian Dhurra; and in the South African colonies as mealies. The germ of the grain is very rich in fat which gives rather an unappetizing smell to the meal, and is somewhat deficient in albumenoids, though fully supplied with carbohydrates.

The meal, which does not mix readily with water, is used by many nations for food-making. In Italy "polenta," a kind of maize porridge of varying degrees of fineness, is almost a fundamental article of consumption, while the Indians of Yucatan make their "Tortella" from maize flour. Maize starch, or cornflour, is largely employed in biscuit making and as a substitute for arrowroot; but for bread 25 per cent of wheat flour at the very least should be added to the maize.

The young unripe cobs are sweet and palatable as a vegetable, and the oil extracted from the grain supplies a useful edible oil.

The ripened seeds "pop" or burst when roasted and

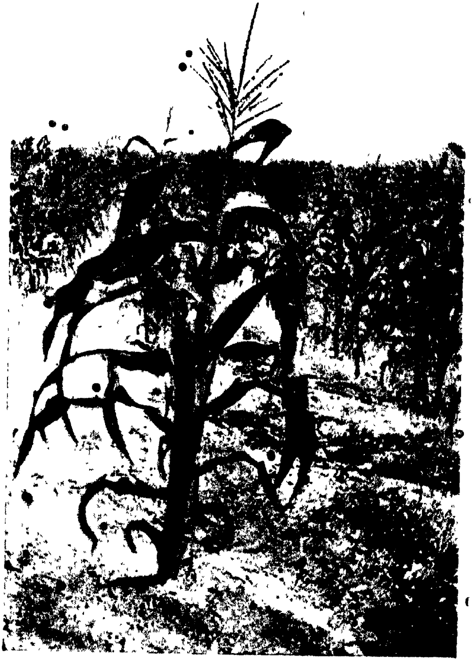

FIG. 3

MAIZE PLANT

the inside swells out considerably, and is of agreeable flavour; the harder varieties are best for this purpose.

A valuable feature of maize is the fact that its hard skin renders the whole plant sufficiently tough to resist the damage of either fungus or beetle. Nearly all the damage arises after harvesting, when the maize fly (*palomila*) and other beetles commit great havoc during storage, necessitating fumigation in some cases. The grain also must be dry before shipment or heating and fermentation may cause great loss.

It is not difficult to distinguish the American "horse-tooth" form with its clear bright colour from the much smaller-grained Italian type, or from the large red coloured Hungarian product.

The presence of a horn-like substance in maize, in which the starch granules are embedded, necessitates a chemical process in the separation of starch. The high content of oil also demands modifications in the methods used for other grain. After passing through a cleaning process the grain is steeped in warm water (100° F.) containing a small amount of sulphurous acid, and then the acid process, which we will describe first, is used.

The steeping vats are usually of wood and are provided with the necessary pipes and outlets for the wash water and grain. The operation, which requires about three days, must be continued until the grain is quite soft. The acid can be produced as required in the starch works by burning sulphur and collecting the gas in water. Various types of sulphur-burners are in use, and the absorption of the gas is effected in a small tower containing a packing of coke and supplied with cold water. The liquid flowing from the apparatus contains quite a small percentage of acid.

The softened grain may be ground in an ordinary

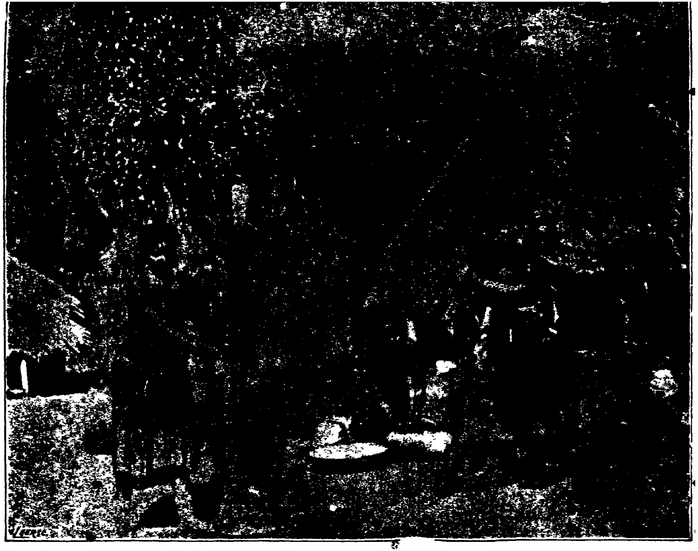

Fig. 4

KAFFIR WOMEN GRINDING MAIZE OR MEALIES

type of mill, but fluted rollers are usually used when the "germ" which is separated is to be employed in the production of "corn oil."

The ground pulp is next washed by powerful jets of water on shaking sieves, and yields a starch still mixed with a considerable amount of gluten. This impure product is again treated with sulphurous acid and purified by fine sieves. Owing to the rather large amount of water, a preliminary separation of a portion contained in the starch-milk is often necessary. The concentrated liquid is then made to flow through long inclined troughs or "tables." An even flow is essential, and any irregularities are smoothed out with a paddle.

For employment in the manufacture of syrups and glucose, the starch can be used at this stage without further treatment. When the alkali process is adopted, the concentrated starch-milk mentioned above is agitated with a weak solution of caustic soda to act upon the gluten. The separation and refining is then conducted in the manner already described when dealing with potato starch.

The drying process can be modified to produce either the so-called crystal starch or the lump quality. Crystal starch results when the drying is carried out, slowly at first, at a fairly low temperature (40° C.) followed (after scraping away the discoloured outer layers and wrapping in paper) by a higher temperature (60° C.) and faster rate. Lump starch is slowly dried at gradually increasing temperatures, the whole process occupying more than a fortnight.

Starch produced by the acid process is of a fine white colour but does not yield a thick paste. "Thin-boiling" starches are much used in the textile industries, but in most cases are not of much use as adhesives or stiffeners.

The importance of *millets*, a term which includes a large number of small-seeded cereals, is hardly appreciated in this country, but in India alone 40,000,000 acres are devoted to the crop, and China, Japan, and Korea consume enormous quantities. A bewildering

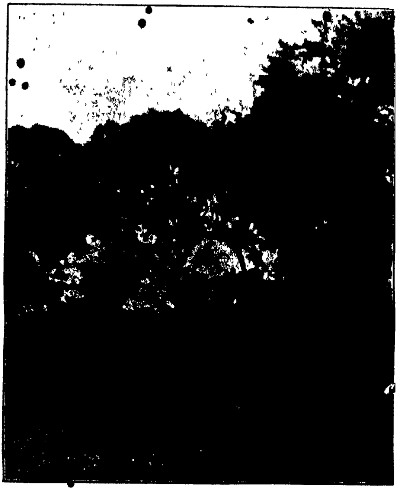

FIG. 5

CHINAMEN THRESHING MILLET

variety of names and considerable confusion in the botanical nomenclature prevails throughout this group of plants.

The Italian millet (*Setara italica*) and the Hungarian species are now probably the most cultivated. The abundance of millet grain found in the lake-dwellings clearly indicates its importance as a food in prehistoric times, and there are records of its use in China about 3000 B.C. Much is grown for forage purposes.

The Barnyard millet (*Pannicum crus-galli*), grown in the United States, belongs to the genus *Pannicum*, and is known in India as "Bharti." Other important but smaller Indian millets are the "Shama" and "Sanwa." The diet value is not very high, but their grains when boiled in milk are much used as a human food ("khir").

Common millet (*P. miliaceum*) or brown corn millet is generally regarded as the true millet. It is extensively grown around the Mediterranean, in Russia, China, and Japan (Fig. 5).

Sorghum, Durra or Guinea corn (*Andropogon sorghum*), generally looked upon as a native of South Africa where it is known as Kaffir corn, is a cereal grass containing much saccharine substance, which is very largely used for human food in India, Africa, and China, and elsewhere to an even greater extent as fodder, especially in Australia. Only mature sorghum must be used as cases of poisoning, arising from the presence of hydrocyanic acid under certain conditions in the young plants, have occurred (Fig. 6).

A less known plant, but nevertheless affording an important foodstuff, is Korakan or Ragi, a tall annual grass (*Eleusine coracana*) yielding an abundant crop even when grown on a very poor soil. Its practical immunity from attack by insects is clearly advantageous in tropical countries. In Mysore the meal is made into cakes which are fried in oil; in other parts of India a fermented liquor is prepared from the grain.

Pearl millet (*Pennisetum typhoideum*) is much cultivated in the Bombay Presidency, and on account of its heating qualities is also largely consumed by the tribes of northern India, and, made into bread and cakes, the grain is considered very nutritious.

FIG. 6

MILLET AND SORGHUM FIELDS NEAR PEKIN

Buckwheat (*Fagopyrum esculentum*), strictly speaking not a wheat at all, nor in fact a cereal, is a somewhat recent introduction as compared with other food plants. A reference to its cultivation is found in a German work of 1436. It is not much grown in England, but constitutes the principal means of subsistence in some parts of Russia, while buckwheat cakes are a special dish of the United States. Its three-cornered grain (*Greechevnaya krupa*), like a small beech-mast, is characteristic, and originated the name *buck*, the word for beech being in German *buche*, in Russian *buk*.

# CHAPTER VI

## RICE

In tropical and sub-tropical regions rice is the staff of life, in fact it is the principal food of more than half of the population of the world. Its cultivation extends far back into the dim past, its original home being most probably south-eastern Asia.

In the annual ceremonial sowing of important plants, inaugurated by the Emperor Chin-nong, in 2800 B.C., rice must be sown by the Emperor in person, but the other four, millet, wheat, barley, and beans, might be sown by the princes of his family. There is no word for rice in the *Zend Avesta*, which seems to dispose of the Persian origin which has been held by some. Herodotus also mentions only wheat as the staple food of the Persians, and Chinese annals state positively that there was no rice or millet in Sassanian Persia. Rice, however, was plentiful in the Sassanian epoch in Kashgar, Khotan, and Tashkind.

As far as Europe is concerned the first recorded rice growing was near Pisa, in 1468.

The origin of the Carolina rice trade was of an accidental character; a boat from Madagascar put into Charlestown through stress of weather, in 1694, and the captain paid a visit to Thomas Smith, the governor. Smith wished to try rice in a swampy part of his garden, and the captain gave him a small bag of it which he happened to have on board. The experiment proved a brilliant success and was the beginning of the flourishing industry of Carolina.

The scientific name for rice is *Oryza sativa*, but as is usually the case with most plants which have been cultivated for long periods, the number of varieties is very large.

From a study of various catalogues it might indeed be possible to infer that there were now 1,500 or more representatives of the original wild stock. And we may with absolute certainty count up sixty-one definite Eastern varieties, about half of them the familiar hard kind, the rest the soft glutinous grain preferred by the natives of Burma and the neighbouring states.

The group represented by *O. glutinosa*, the source of "pulut" in the Straits Settlements, and of "ketan" in Java, does not appear to contain much starch but a "substance near to sugar" (? Inulin). On boiling, the grains do not remain intact but form a soft sticky mass of distinctly sweet flavour.

The rice plant, in place of a compact "ear," bears a head made up of a number of fine stalks, each of which contains one grain. These grains, covered with a brown husk, are easily detached, and in this condition are known as padi (or paddy).

Rice plants, excepting upland, or hill varieties, require fields which can be flooded or kept dry as required, and much labour is expended by native races in cutting the slopes of hills into terraces (Fig. 7). The whole hill-side is turned into a series of shallow pools arranged in steps. If the water supply is not available from natural sources this is produced by mechanical means, and a great variety of remarkably ingenious devices are used, some moved by man-power, others by primitive paddle-wheels worked by streams (Fig. 8). The water is retained in the field, or rather seed-bed (as these are usually quite small), by ridges of earth. The slightly sprouted seed is sown broadcast, and rather thickly, in the bed, which has been turned into a fine mud.

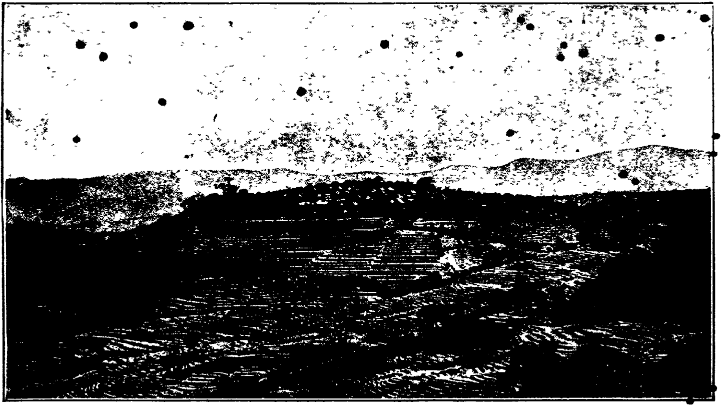

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FIG. 7

TERRACED FIELDS, VISWENA
(From Hutton's "The Angami Nagas")

When the young plants are established, which is soon the case, the water is drained off during the daytime, and run on again at night. By this means the young plants are kept warm at night and exposed to the air during the day.

In the interior of Sumatra rice is sown by women, who, in sowing, let their hair hang loose down the back, in order that the rice may grow luxuriantly and have long stalks, an instance of homoeopathic or mimetic magic.

The shoots when about nine or ten inches high are transplanted, and set out in small groups in the prepared fields. The same alternate flooding and aeration is continued for a short time, and then permanent flooding is kept up, until the rice begins to ripen, when the beds are gradually allowed to become dry.

In Louisiana and Texas the rice lands are allowed to grow sufficiently dry to permit the use of harvesting machinery in place of the laborious hand reaping usual in most other rice areas.

A simple form of threshing removes the grain from the stalk. Cleaning is generally deferred, as the rice will keep better in the unhusked condition.

Where rice is one of the main food-stuffs the husking process is done daily. The padi is beaten and pounded with a pestle, or large wooden mallet, in a stone mortar or wooden tub. The shapes, sizes, and patterns vary greatly in different countries (Figs. 9, 10).

Great ingenuity is displayed by native races in devising simple machines to save labour, including the adoption of buffalo-power and water-wheels. The pounding cracks the outer husk which can then be easily removed by winnowing, and by these primitive methods a valuable food product is prepared. But in England the elaborate system of milling and polishing almost

FIG. 8

IRRIGATION PUMP WORKED BY THE FEET, IN INDIA completely deprives the rice of the valuable "accessory food factor" which exists mainly in the outer layers of the grain, the nutriment value of the part removed by polishing being roughly twice that of the polished grain. A similar state of affairs is also found in the milling of very white flours from wheat.

At the penal settlement on the Brisbane River, Australia, where the capital of Queensland now stands, convict labour was employed at very great cost to drain a swamp, the authorities considering that it would make the right sort of land for growing rice. Then, instead of sowing the grain in its natural state of padi, they used manufactured rice, and as, naturally, no crop appeared, a report was sent home to England that the convict settlement had not soil suitable for rice cultivation!

A recognition of the absurdity of grading feeding stuffs by appearance must surely cause the present custom to give place to a grading by food values. A certain writer, indeed, when commenting on the above method of pricing and valuing rice according to its polish, and on similar proceedings, suggested that on the same principle boots should be priced in accordance with the degree of polish they will take!

Rice in its unpolished condition is one of the best of the cereals, even better than wheat, the gluten of which, though it enables bread to be made, is not of high food value, while the deficiency of proteins in rice may be partly compensated by the addition of peas and beans which grow readily throughout the tropics. The Soy or Soya bean, a native of Eastern Asia, has been, for instance, cultivated in China and Japan for a very long period, where it is the most important leguminous plant grown, and is used extensively as a food for human consumption, because its high content of

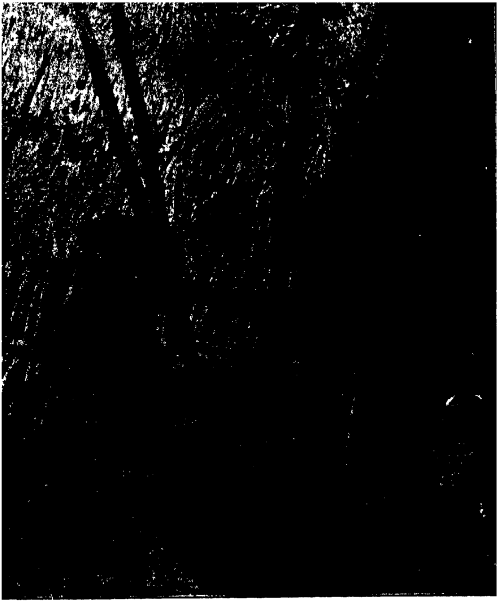

FIG. 9

CHILDREN POUNDING RICE IN INDIA

protein and oil makes it peculiarly valuable as a supplement to such fare as rice, with its starch proportion of sometimes 83·8 to 85·7 per cent.

It is better to steam rice grains until the starch granules are fully swollen than to boil them since in the latter case much of the nourishing value is also lost.

Rice-fields are subject to attacks by many injurious insect pests. The larva of the rice water-weevil feeds amongst the roots and causes much damage to the crop, the rice worm (*Tylenchus angustus*) can apparently migrate over dry ground, if the air is humid enough to form a film round the worm's body, a fact which accounts for the practical immunity of spring rice when the air is driest ; the " stink bug " attacks the soft grains when they are forming ; the " fall army worm," or " southern grass worm," occasionally becomes abundant and invades the fields in the spring, but its ravages can be largely prevented by flooding them.

The caterpillar of the " rice stalk borer " feeds in the stems and causes the head to die. These pests can, however, all be controlled by thorough cultivation, by suitable flooding and draining, and by keeping the banks clear of weeds.

There are also two destructive rice-leaf hoppers. These may be trapped by making use of their strong predilection for light, but owing to dread of evil spirits, it has been found almost impossible to induce the ryots to go to the fields at night to light the lamps. Perhaps some immune variety of padi may yet be discovered, or a way out of the difficulty learned by a study of the relation of the ripening time to the incidence of the pests.

Owing to the damage wrought by vast numbers of ducks on the rice-fields of California, an aeroplane patrol was established in 1919, and charged with the

FIG. 10

CLEANING AND POUNDING RICE AT MANILA

task of flying over the fields to scare away the birds, and the method proved so successful that five planes are now kept busy making flights both by day and night.

There is a wild rice (*Zizania aquatica*) known as kau-sun in China, and sometimes as Canadian rice, which is used as an important starchy food amongst some American aborigines. It thrives on a slightly salt soil and so has been investigated as a possible useful plant for cultivation in situations which are unsuitable for most other cereals. The plant, apart from its seeds, is regarded with esteem as a vegetable in China, and might probably be cultivated in suitable localities in the United Kingdom.

The world's rice trade has two branches: (*a*) Far Eastern, requiring a cheap rice for feeding the native population; (*b*) Western, requiring large quantities of medium quality, and smaller amounts of a high quality product. In 1913 India (chiefly Burma), Siam, and Indochina together contributed 94 per cent of the world's exported rice and padi.

The material which is usually available for rice-starch production consists of sweepings and residues from the mills, or damaged grain which is not fit for food purposes.

Fermentation due to bacteria is liable to occur, particularly during steeping and settlement, and may cause serious loss. The chief source of this bacterial infection seems to be the grain itself, and it has been found that "polished" rice carries more bacteria than "unpolished," a fact apparently due to the removal, with the grain-husks, of an alkaloidal substance which has antiseptic properties. Ordinary padi as it comes from the fields carries sporing bacilli which are capable of fermenting the starch with the production of acetone and butyl alcohol, as much as 8–9 per cent of acetone on the weight of rice taken having been obtained.

Owing to the ease with which crushed rice forms masses or lumps, the steeping vats are provided with mechanical agitators which are maintained in motion the whole time. The simple washing out process, however, is probably no longer used as its production is low. An English patent specification (1920) suggests steeping the rice grains for a few hours, followed by grinding, until 98 per cent passes a 130-mesh sieve, water being added at the same time till the resulting paste contains about 40 per cent of solids. The separation may be effected by centrifuging or decantation.

The starch granules in rice are very small and the nitrogenous contents of the grain high, a fact which necessitates the employment of chemicals to separate the starch in a pure condition. The use of damaged grain also introduces complications in the process, making the corresponding operations more difficult to control than in the case of wheat, and fermentation methods have not proved successful.

The use of caustic soda, apparently introduced about 1840 by Orlando Jones, is, with a few modifications, still employed. The steeping is carried out with a weak solution of caustic soda in large cement tanks, and requires a day or two to complete.

The temperature must be kept fairly low; in fact, artificial cooling is occasionally employed to prevent the action of the soda becoming too energetic, and also to restrain fermentation which causes loss of soda and other difficulties in the later stages of treatment. The mass from the vats (with the addition of a further quantity of caustic soda solution) is ground either by rolls or stones, or, in some cases, by pebble mills. The separation of the starch is accomplished by sieving, to remove the coarser particles of cellulose, etc., followed by centrifuging or settling, as previously described.

The complete removal of the gluten may entail several repetitions of washing and separating processes.

In the older methods, the wet starch is brought into convenient form for drying by putting it into boxes provided with perforated bottoms covered with filtering cloth. The boxes are occasionally shaken by hand labour to assist the separation of the water, so that after about twenty-four hours the amount remaining in the starch is about 45 per cent. The boxes are then tipped, and the blocks of moist starch cut into squares of convenient size for removal to the drying chambers. The chief drawback to this method is the extensive area occupied by the boxes and the labour involved in washing the filter-cloths. The filtration may be hastened by the use of a suction filter, or more expeditiously by a pressure filter, though the water content differs but little from that found when boxes are used without additional machines. The water in the blocks evaporates on the surfaces, and a yellowish colouration resulting from the matter present in solution, chiefly dextrin, is produced.

The outer coloured surface must be removed by scraping, which is not an easy operation owing to the brittleness of the blocks when dry. To obviate this breaking up, the scraping should be done when the water content is reduced to about 30 per cent, or rather less, by exposure for a couple of days in a drying chamber at about 60° C. The removal of water may be also assisted by placing the wet blocks on porous tiles. At this stage of desiccation the removal of the outer layer is not difficult, and the blocks can now be subjected to further drying without the development of a coloured layer.

The scraping is usually done by hand, but planing down by machines fitted with rotating cutters allows a more rapid working. The quantity pared away is roughly equal to 25 per cent of the whole starch.

The well-known form of starch in tapering prisms is the result of the cracking which is caused in the drying of the blocks.

Any slight tendency to yellowness in starch may be corrected by the use of ultramarine and certain other colouring matters, which are stable in air and unaffected by the presence of chemical traces as, for example, of caustic soda which may have been used in the preparation of the starch.

The manufacture of the popular prismatic form of starch requires considerable care, as the desired smooth appearance, good fracture, and large prisms are achieved only by careful work throughout the whole series of operations, and special attention must be given to avoid any secondary fermentation processes.

# CHAPTER VII

## SAGO, YAM, AND OTHER STARCHES

SEVERAL well-known articles of food consist mainly of starch, and of these sago is probably the best known.

Genuine sago is prepared from several kinds of palm trees. The typical sago palms (*Metroxylon*) live in more or less swampy localities, and, like many other palms, they flower only once and then die. The following varieties are the most usually selected: ***Sagus rumphii, S. farinifera, S. borassus flaballiformis, S. laevis,*** and *Arenga saccharifera.* Some of the *Cycads* (***Cycas circinalis*** and *C.* ***revoluta***) are known as false sago palms.

The flowering happens when the plant is about eight or more years old, and just before this takes place the whole stem of the tree is loaded with starch. This is the period chosen for felling. Then three trunks, 15 ft. high and 20 in. in diameter, yield approximately about as much starch as an acre of wheat. After cutting down the trunk the root-stock does not die but sends up new shoots, which grow to a considerable height and girth. The wood of these shoots is very weak and the stem is made up mainly of the pith.

The procedure in Borneo is described by visitors as follows: The trees are felled when about 25–30 ft. high, the trunks are stripped of leaves and cut up into sections about 3 ft. long. Each piece is split lengthwise and the soft fibrous tissue is scraped out with a wooden hoe. Successive washing and straining processes serve to separate the starch granules. The milky water coming from the troughs in which the pith is kneaded is collected and allowed to settle, and when the deposit is nearly dry it is forced through holes in a perforated sheet of iron, and is then hardened in a shallow pan over a fire.

Sago for home consumption is produced from the moist starch by forming it into cakes, which are baked on hot plates; sago for export to Europe by drying it to a dough with artificial heat just sufficient to cause the appearance of starch paste in the mass. This stiff dough is then pressed through sieves to make the grain-like shape of the finished article.

It must not be forgotten that the name "sago," though originally applied solely to the products of tropical plants, has gradually come to mean rather a description of a particular shape or form of starch irrespective of its origin.

The manufacture of artificial "sago" is, in the main, similar to that used in the production of real sago. A pasty mass of exactly the right consistency is forced through a sieve or a plate perforated with round holes. The short sago cylinders, after passing through the holes, are allowed to dry a little in order that they may not adhere in the next operation, which is the rounding of the cylinders by rolling them over and over in a barrel mounted on an axle. These circular pellets are graded according to size, and then subjected to hot steam for a short time, which produces a thin film of starch paste on the outside. The final drying is done by hot air. The simulation of real sago is carried further still by producing slightly tinted grains, the yellow usually by a trace of caramel, or by "browning" on a hot plate, the reddish tint by a trace of rouge. It is very difficult to distinguish by the external appearance manufactured sago from the natural article from the palm tree.

In Java the Gomuti palm (*Arenga saccharifera*) supplies the chief food of the natives, but it is of unappetizing taste and appearance to most Europeans.

Another "sago" has its origin in the Batata, or sweet potato plant, frequently blended with starch from other sources. Sweet potatoes are the thickened roots of *Ipomœa Batata*, a climbing plant belonging to the bindweed or convolvulus family. This is extensively cultivated in most tropical countries, although not known in a wild state. The root contains much starch and sugar, and takes the place of the ordinary potato. In the United States a semi-large-scale plant has been erected for the production of syrup from sweet potatoes, which is stated to be suitable for baking, sweet-making, and other table purposes. The flour has so far not been very satisfactory.

The boll weavil has rendered the growing of cotton unprofitable in large areas, and on this account new methods of cultivation of sweet potato are being studied, including means of combating *rhizopus tritici*, which is responsible for large losses of various vegetables during storage.

Yams, the tubers of various species of Dioscorea, are also cultivated in nearly all similar countries. The black bryony of our hedgerows, by the bye, is a close relative of theirs and has a large underground tuber. Yam tubers are very rich in starch and often reach a large size, weighing as much as 30–60 lb.

In some parts of the West Indies the unripe fruits of "soursop" are used to prepare a kind of arrowroot. Other examples of plants which are used for the local production of starch are: Mango, banana, plantain, coco-nut palm, and Palmyra palm.

A variety of starch, called "talipot," is obtained from the palm *Corypha umbraculifera*, and is known in Ceylon as palmira root flour. Recently also excellent starch has been produced, though on a small scale, from the bread fruit.

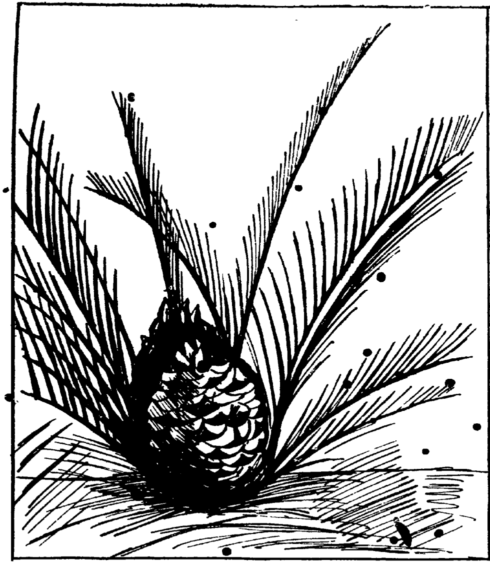

FIG. 11

ZAMIA PALM—FEMALE (from a sketch)

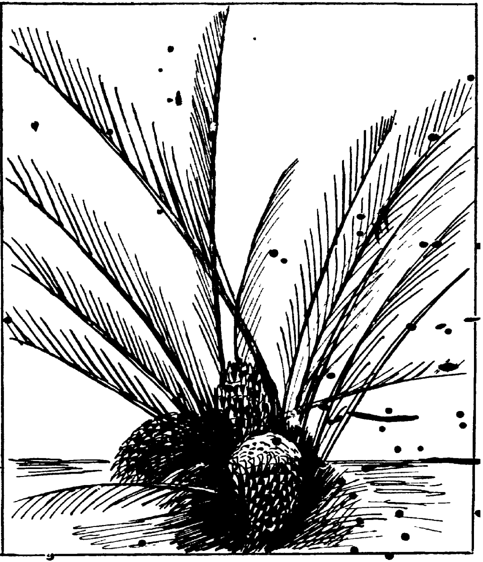

FIG. 12

ZAMIA PALM—MALE (from a sketch)

A tuberous plant (*Polymnia edulis*), growing in the Andes, has been examined as a possible source of starch, but the carbohydrate content is only about that of mangolds, though the weight of the tuber, about 2 lb., is favourable.

Salep is a starchy product with the appearance of horny yellowish lumps, prepared in Asia Minor from the roots of various plants of the orchis group. A similar extract can also be made from the common European varieties, and from an Indian species. These preparations are reputed to possess important medicinal properties.

As a result of investigations in New South Wales, a company, the Australian Starch Co., has been formed to produce starch from the Zamia palm (*Macrozamia fraserii*). The aborigines use the nuts and centres of this palm as food, but they expose the crushed substance to the air and wash it in several changes of water to get rid of a poison which paralyses the hind quarters of cattle if they eat the plant, as they are apt to do in dry seasons (Figs. 11 and 12). It is proposed to work up Zamia bulbs from an area of 31,000 acres in the neighbourhood of Currawan, and an annual minimum of 100 tons of starch is expected.

The extraction of starch from the Burrawang palm is also being undertaken on an experimental scale on the Clyde river, N.S.W., by a method of stripping the tree of its fibre coat, and paring it down until the core is reached. The pith is then minced and the resulting pulp is freed from fibrous material by sieves and the starch purified by the usual washing and settling out process. The crude material is dried in an evaporator, and in about sixteen days the mass breaks down into " crystals."

The large beans of the Moreton Bay Chestnut

*Castanospermum Australe*) may be converted into an excellent starch, though analysis has discovered in them traces of saponin, which poisonous element must be first eliminated before they can be safely used. This tree is not, however, common enough to make the use of its beans for starch-making a commercial success. The beans form one of the chief vegetable foods of the aborigines, but they always soak the pounded or shredded meal in water for several days before cooking it, which renders it perfectly wholesome.

Horse chestnuts (said to have been introduced into Europe from Thibet about 1550) are, too, a possible source, as suggested by Hedenus and Flaudin, also by Murray in 1796, and have, in fact, been so used. They contain 2–3 per cent of fat, 6–7 per cent nitrogenous matter, 20–23 per cent of starch, but owing to the presence of the poisons known as saponins, the flour cannot be used as a food stuff without treatment to remove them. Factories were erected near Paris some time ago, but they did not prove remunerative owing to the cost of labour and transport.

The hard outer shell must be first taken off, and this is done either by drying until easily loosened from the "meat," or by steeping for a short time in boiling water. After a preliminary crushing, remnants of the husk can be removed by floating them off with water. A second crushing to a finer pulp follows, and the further treatment is much the same as that already described. The only point of interest is the fluorescent appearance of the wash water produced by the substance known as aesculin, which is also responsible for the bitter taste of the starch, which is of a somewhat low grade. Horse chestnuts may therefore be regarded rather as a possible raw material for the fermentation industries than as a source of starch.

# CHAPTER VIII

## ARROWROOT, CASSAVA, TAPIOCA

THE name arrowroot is probably derived from a native word *Ara-ruta*, meaning merely root, though some botanists consider that the root of *Maranta arundinacea* has been confounded with *Maranta galanga*, which was called arrowroot because it was used as antidote to the venom of *Manihot utilissima*, employed for poisoning arrows.

Arrowroot, as a general term, means a starch product contained in a variety of plants; most of the West Indian arrowroot coming from that known as *Maranta arundinacea*, while *M. nobilis*, *M. allonia*, and *M. ramosissina* (East Indies) are also grown for their starch-giving powers.

In addition to the Marantaceae group, arrowroot is also made from *Arum maculatum*, and the product from this source is spoken of as Portland arrowroot, since this arum was formerly much cultivated in the Isle of Portland.

East Indian arrowroot is obtained from *Curcuma angustifolia*, and is manufactured also in Travancore and N.W. India.

Tahiti or Tacca arrowroot is derived from *Tacca oceanica* or *T. pinnatafida*.

Brazilian arrowroot is the product of many varieties of *Jatropha manihot*, which will be described at greater length, since it may be regarded as the best representative of the starch-producing plants of the type which we are now considering.

The variety of arrowroot known as Tous-les-mois or

Tulema, is obtained from several plants closely allied to Maranta, and is manufactured in the West Indies; chiefly in St. Kitts, where the *Canna edulis* (*Ker-gawl*), flourishes, and was first introduced into England by Wordsworth in 1836. The size of the granules is very characteristic, since they are much larger than those of any other kind of starch, not excepting that from the potato.

In Bermuda the cultivation of starch-producing plants is graduallv giving way to more profitable crops, and St. Vincent is now the chief seat of arrowroot culture in the West Indies.

In Jamaica the tubers are taken when about a year old, washed free from earth and pounded to a pulp in a large deep mortar. This pulp is mixed with fresh water and strained through a cloth or hair sieve. The milky liquid is allowed to settle and the separated starch, after further washings, is dried in the sun. In Bermuda, in the places where the trade still lingers, the roots are first peeled to remove the thin skin, which causes a yellow colour and bitter taste in the starch if allowed to remain.

Tapioca is chiefly produced from the various varieties of *Jatropha*, which flourish in the West Indies, South America and the southern part of North America.

The name cassava should properly apply only to the meal obtained from the roots of the plants, but it has passed into use to designate the plant itself. Cassava starch only differs from tapioca flour in being of a less lumpy character and appearance. Flake and pearl tapioca are partially cooked products, as will be noted later.

A less confusing nomenclature is to restrict the name *manioc* to the plant, *cassava* to the starchy substances derived from its tubers, and *tapioca* to the product manufactured from its starch.

The methods used by native peoples for the extraction of cassava are primitive in character but present some features of considerable interest. Modern methods now used follow fairly closely the series of operations already described.

The manufacture of cassava starch has a great advantage in that the whole treatment is accomplished in about three days, whereas maize starch requires about a fortnight. The manufacture must be carried out as rapidly as possible with no delay between the various steps, otherwise souring, with all its disadvantages, is sure to occur.

The manioc plant is cultivated for its starchy roots which are used extensively as human food, especially in the tropics, as food for live-stock, and for the manufacture of starch.

It belongs to the *Euphorbiaceae* (milkworts), and is a native of Brazil whence it has been carried to all the warmer parts of the world. It is probable that the many forms which now exist have been developed by centuries of cultivation under widely different conditions. The principal forms are known as *Manihot utilissima*, or bitter manioc, and *M. aipi* or sweet manioc.

Six varieties are reported as growing in South America when the Spaniards arrived there. There are also, apparently, innumerable others besides the two main species (*utilissima* and *aipi*) mentioned, some of their names being botanical synonyms, as *M. edulis, Jatropha manihot, Janipha manihot*; and others the provincial designations, such as Yuca brava, Mandioca, Bara, Banankou ogouma, Camanioc, Hednock, Juquilla, Tzün. All the above, however, refer to the bitter varieties. In a similar list of sweet varieties we have *Manihot palmata, M. dulcis, Jatropha dulcis, Yuca dolce, Aipini, Bantara,* etc.

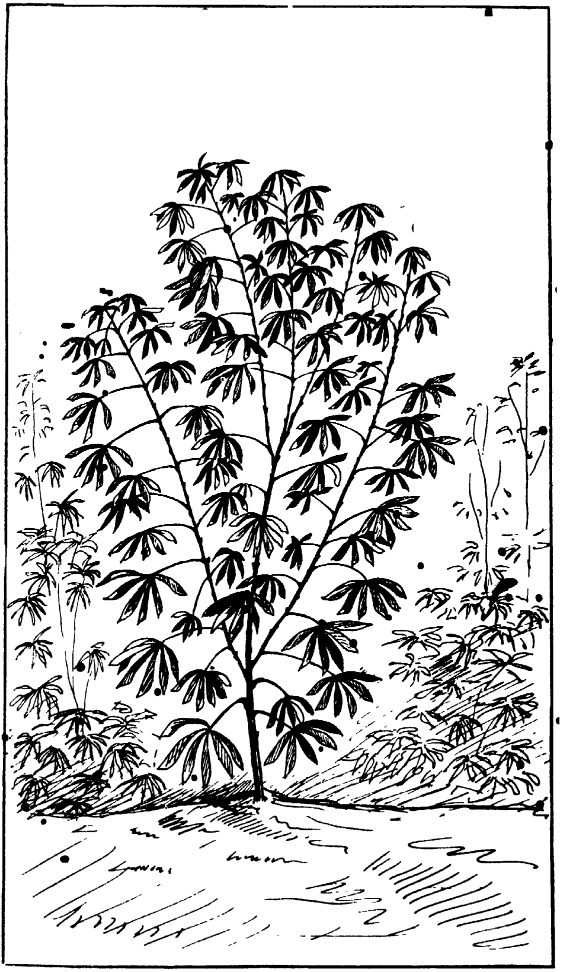

FIG. 13

MANIOC PLANT

(from a sketch)

The habitat of the manioc plant may be best described as including all the territories lying within 30° of latitude on either side of the Equator, and it seems that South America is certainly its original home, Portuguese travellers of the fifteenth century mentioning the tuber as being grown there for food by the natives.

The plant grows as a bushy shrub usually 6 to 8 ft. high, although 16 ft. is occasionally attained. The number of the blades making up the leaf vary considerably both in size and number, there being, for example, a nine-leaved variety, "multifida," and a narrow-leaved one, "genuina" (Fig. 13).

The flowers usually grade from light greenish-yellow to greenish purple. The roots, the most valuable portion of the plant, grow in clusters from one end of the seed canes planted in the soil. Single roots are 1½ to 2½ in. in diameter and up to 5 ft. or more in length, an average cluster of roots weighing 5 to 10 lb., though occasionally attaining to a weight of even 30 to 50 lb.

All the varieties of bitter manioc, the most important as starch producers, contain a certain amount of poison, but fortunately this is very volatile and may be entirely dissipated by moderate heating or by exposure for a few hours to the sun, and roots which have been cooked may be eaten with perfect safety. The bitter manioc is the source from which nearly all tapioca is manufactured, and it also forms the principal bread-substitute food in many tropical countries.

Cassava manufacture made considerable progress in the United States in consequence of the partial destruction of the Florida orange groves in 1894–5. Corn and other grains do not yield good returns on the light sandy soils, so manioc was tried as a less expensive substitute, and soon proved itself an important factor in solving the problem of stock-growing at a profit.

The manioc is very liable to the attacks of the "cooshie" ants, and their habit of cutting off fair-sized pieces of leaves, flowers, fruit, and seeds, which they carry back to their nests held upright in their jaws, has earned the title of "parasol ants." The regular tracks along which they march in two streams going in opposite directions have been known to extend for a distance of half a mile. The nests may measure as much as 30 ft. in diameter. The pieces of leaf, etc., are not directly used for food but, as first suggested by a mining engineer (*The Naturalist in Nicaragua*, by Thomas Belt), they are used to form beds on which they grow a species of fungus which serves as food both for themselves and their young. The material, on arrival at the nest, is cut up very finely and kneaded with the feet and jaws so that the resulting brown mass shows nothing of the original leaves. The particular fungus is cultivated with minute care and all alien growths are prevented. The cultivation has been so intelligently carried out that the ants have been able to produce a new strain of fungus differing from the "wild" forms. Without this special food the ants die of hunger. By the use of carbon bisulphide the nests can be destroyed with certainty.

We find in Sir Edward Im-Thurm's *Among the Indians of Guiana* a description of the method of preparing cassava adopted by the natives. Women squat on the ground and peel the outer rind from the roots with a large knife. Each root, after the peeling, is thoroughly washed, and is then taken in hand by another woman, who scrapes it vigorously up and down a rasper made of a short board studded with small fragments of stone fixed by resin or balata. One end of the rasper stands in a trough in the ground, the other rests on the woman's knees. As the pulp slips from the scraper into the trough, it is collected and placed in a long narrow cylindrical bag which hangs from the roof of the hut. The bag, known as " matapie," is woven from the pliant cuticle of the Ité palm, and it is used for squeezing out the poisonous juice. This is effected in one of two ways ; a common practice is to suspend a heavy weight from the lower end of the tightly-packed matapie, the resulting pressure being sufficient to squeeze the poison out of the pulp through the sides of the bag. In the other method a heavy lever is passed through the loop at one extremity of the matapie, and one end fixed to the floor. The woman seats herself on the lever so that her weight exerts a powerful pressure on the bag, which is thus drawn taut.

The pulp is converted into flour by pulverizing, and largely freed from debris by sifting. A further drying on a slightly warmed plate, not sufficiently hot to cook it, furnishes the finished product. The small white or yellowish grains are known as " conac " or " havena " in Brazil, where it is the staple food of many native races.

A very fine grade of starch is separated from the juice by allowing it to stand undisturbed. A series of washings (sometimes assisted by water slightly acidulated with lemon juice) are thought necessary. The resulting flour is correctly named Brazilian arrowroot.

The yellow colour is usually esteemed by the natives and is sometimes enhanced by the addition of curcuma.

After separating the starch the poisonous juice is boiled until it has the consistency of treacle, in which condition it possesses no poisonous properties. In the West Indies it is then known as " cassareep," and is used in the preparation of various sauces (" pepper pot," " cabiou," " tucupi "). It also seems to possess some antiseptic properties and on this account has been found useful in preserving food and, according to some authorities, as a remedy for ulceration and ophthalmia. In Guiana the natives treat any symptoms of manioc poisoning, such as may arise from inefficient cooking of the juice, by red pepper moistened with rum.

Cassava cakes are prepared by filling a circular ring, resting on a hot plate, with moist cassava flour. As soon as the mass is sufficiently solid the ring is removed, the cake turned over, and the other side of it cooked. These cakes are described as tasty and appetizing. There are many other methods of cooking cassava less primitive than that just given; the addition of butter, eggs, and sugar, would doubtless give a more European flavour to the cakes.

Owing to the liability of fresh manioc root to rapid fermentation, a quick desiccation is essential. In districts where the sun temperature is high and the nights are not damp drying in the open is possible. In most climates, however, artificial heat must be employed, and care taken that the temperature remains below that at which the starch is altered. For starch manufacture the roots are worked up within twenty hours of digging, as fermenting roots cause difficulties in the separation of a good starch.

The cleaned roots are rasped in machines of either the external teeth type, or, better, the internal teeth type as designed by Champannois in 1866.

The resulting pulp is carried away in sacks or baskets to the press; and the final drying is done by exposure to the sun or by gentle heat in a drying chamber.

In some districts, notably in Java, after removing the outer skin, the roots are cut up into slices and dried in the sun, when they soon lose the water they contain and become white. In this form, the manioc, or cassava, is stable and can be exported, as is also the case with the dried roots destined to be ground to form cassava flour.

Tapioca is made from a still slightly moist starch, the drying being interrupted at the desired point. About 10 lb. of the starch are put into a steam-jacketed copper pan. The cooking lasts until—generally in a few minutes—the mass just shows a tendency to stick to the cooker. Then it is detached from the pan with a small shovel, and, by deft movements, the tapioca is turned over until it is uniformly dried. This operation also lasts a few minutes only and gives the characteristic shiny appearance.

The process requires considerable skill and practice, both hands being vigorously employed in stirring the starch mass with primitive forks, usually made from the worn-out blades of a rasping machine. About 10 lb. of starch produce about 6 lb. of dry tapioca, the loss representing little except water. Further drying follows the cooking process either on shallow heated copper trays or by hot air.

With the trays about four hours is required, but stoves or tunnel dryers need nearly twice as long.

The operation of sorting (" piquage ") and the removal of debris is sometimes done by hand, usually by women and children ; the grading according to the size of the finished tapioca by machines.

Pearl tapioca is made by squeezing the moistened starch through a sieve, producing short rods which are cooked on hot plates heated to about 90° C. by means of direct heat or steam. The mass must be stirred and agitated the whole time.

The description given above applies mostly to the smaller establishments. On a larger scale mechanical operating replaces much of the hand labour. The starting point is the crude lump-tapioca which is granulated by passing between two pairs of rollers and graded according to size. A separation of all dust and light particles is effected by a fan which practically does away with the necessity of sorting by hand.

Different countries have adopted characteristic methods of preparing cassava as food, and the writer has seen a calculation showing that 1¼–1¾ lb. of cassava are consumed daily by each of some hundreds of thousands of people. In Madagascar the natives either eat the dried slices of root or boil them in water, and after the latter treatment it is known as "manioc mahogomainty."

Another recipe is to place the cleaned roots in a bag and moisten them with water, a vigorous fermentation soon takes place, and the blackened roots are considered to be ready when putrefaction is just setting in; the "manioc vonidraiga" thus produced is eaten with meat, fish, etc.

The sweet manioc, which contains no poison, is cooked in ashes, or roasted, braised or boiled in the same manner as potatoes, in this condition being known as "haipin." In Brazil dried meat and beans are added to the boiled manioc. Jamaican manioc, made into thin cakes, is much appreciated in Boston, for eating with tea or coffee. Many Creole families make excellent cakes with the help of sugar or coconut milk.

In parts of India, the roots are used after plain boiling in water, but their flavour when baked is more dainty. Manioc takes the place of bread and potatoes and forms the basis of diet of all the Indian peoples of America, Africa, and Asia. The taste is rather insipid and requires a sauce or something strongly spiced. The juice pressed from the roots is used for making condiments or for preparing a fermented drink.

In some countries the young shoots and leaves are boiled as a vegetable, somewhat in the same manner as spinach.

Cassava flour can be used for bread, cakes, etc., just as any other variety of tapioca, but it is rather less nutritive than wheaten flour and less easily digested.

Tapioca prepared from manioc is, on the other hand, particularly easy of digestion, as in the preparation the starch has been modified and rendered partly soluble in water.

Cassava flour, given with watery food, is an excellent diet for milking cows, and stirred into whey is useful for calves. Cows and other animals (horses less readily) eat the leaves and stems of sweet manioc, but the food is usually made up as a " mash " of fresh roots and flour. Pigs, sheep, goats, and hens all do well on a manioc diet.

A good method of preparing a suitable feed of cassava for cattle is to mix the flour with twice its weight of warm water, and then to scald it with a further quantity, equal to the first amount, of boiling water. By putting the mixture again on the fire and stirring for a few minutes a more digestible form of gruel is produced than is obtainable by adding the whole of the water at once.

# CHAPTER IX

## BLEACHING, COLOURING, USES, ETC.

A VERY considerable improvement in the colour of starch may be brought about by the use of chemical bleaching during manufacture.

Bleaching powder, or (as it is frequently though erroneously called) "chloride of lime," is often used, together with a small percentage of either acetic or hydrochloric acid to prevent the contamination of the solid starch with lime.[1] Bleaching assists the oxidation and the removal of all traces of gluten and colouring matter. But this operation must be followed by a very thorough washing. Any slight yellow tint may be masked by the addition of a small quantity of a blue colouring matter, such as ultramarine, Paris blue, indigo, carmine, or aniline blues. Very small amounts are used if it is only the correction of a yellowish tinge, but for "starch blue" a considerable quantity is required.

Many toilet preparations with innumerable names contain starch derived from the potato or rice, incorporated with various perfumes and essential oils, and coloured as desired.

The colour, which obviously must be "fast" to light and to minute traces of either acid or alkali, which might be present, may be added to the moist starch. In any case great care is necessary to thoroughly incorporate the mixture and so obtain a uniform product.

Starch may be formed into rods by "extrusion," i.e. forcing through a nozzle in a manner similar to that used in making common bricks. The stiff pasty mass is prepared by mixing starch flour with starch paste and forcing it through a nozzle of the desired shape. The continuous "rope" of starch can be cut into the desired lengths and completely dried. It is more difficult, but possible, to produce blocks or tablets of starch by compression in machines or by shaping the still moist starch in forms of specially hardened plaster of Paris. The latter method is very similar to the making of bricks by hand.

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[1] Samuel Hall obtained a patent for bleaching starch by chloride of lime in 1821.

For special purposes starch of different origins and qualities is prepared, and the trade name of the commercial article does not therefore always bear much relationship to the source whence the raw material is derived.

Laundry starch may contain borax or other substances to enhance the glossing effect when the goods are ironed. By the addition of a soluble blue colouring matter, "blueing" and starching may be done in one operation.

Wheat starch usually contains some gluten which increases the sticking power of the pastes, but a similar effect is also produced by incorporating partly washed wheat starch with the much cheaper potato starch (farina). By the addition of a little dextrin, or even farina-paste, to farina, a material simulating the product from wheat may be made.

Starches for technical purposes are usually classified as (*a*) thick boiling, or (*b*) thin boiling. Both groups may be subdivided, the thick boiling varieties into "chemicalled," in which alkali has been used, and "unchemicalled," employed mainly in baking powders, etc., and for size in the textile industry. The thin-boiling starches may be produced either by the drying-in process, in which a certain amount of hydrochloric acid is added previous to drying, or by the "in suspension" method. In the latter the hydrochloric acid is added to a suspension of starch in water warmed to a temperature below the gelatinizing point. These products are used in the confectionery and laundry trades and yield a much thinner paste than the thick boiling grades.

Since rather more than two-thirds of the food of mankind belongs to the group of carbohydrates, of which starch is the most important member, it is easily understood that many prepared starchy foods are manufactured. Starch, however, in its unmodified form is far from being readily digested by man, but after cooking it may be with great facility.

Flaked potato, though perhaps hardly belonging to the category of starch, is included here, since it is a product of some starch factories. The cooked tubers are crushed between steam-heated rollers, which reduce the water content sufficiently low to produce flakes which can be stored without difficulty.

The potato pulp residues can be converted into cattle foods, but to prepare a food which will keep in sound condition is not very easy. The water-content can be reduced by pressing, and this may be helped by the addition of a very small quantity of lime. A feed more palatable to beasts results from a lactic fermentation of the pulp in silos, but this material must be mixed with a more nitrogenous fodder. A fodder which keeps much better may be made by a process of drying similar to that used in working up the residues of beet-sugar manufacture. Probably the most satisfactory method is to mix one part of pulp to a quarter part of molasses, followed by drying and kibbling.

Starch, in one form or another, is the most important substance for giving adhesive properties to size, and strength to the yarn. Different starches give a different "feel" to yarn; thus maize starch gives a harsh one, which is not readily removed by boiling, while the other starches produce a softer feel. This is probably due to differences of physical properties.

There is no doubt about the antiquity of sizing or dressing linen; we hear of an ancient process used in India:—"the linen is steeped in rice water varying in strength according to the body to be given to the linen; when it is dry it is spread on a well polished table, rubbed with a shell, and then put under pressure."

The action of diastase (*see* p. 12) is utilized when it is desired to remove starch from wrongly-finished goods and so obviate rebleaching. The cloth is steeped in a malt extract solution for a few hours and the resulting dextrin and maltose washed out with hot water.

Size made from potato starch is largely employed in the textile industries, where it is used for three distinct purposes, as (1) a sizing for the warp before it is woven in order to produce a smooth strong thread without any fluffy projecting fibres; (2) to give a finish to the woven goods; (3) usually after dextrinizing, as a thickener or vehicle for applying colours to the fibre.

For sizing with wheat starch the sample should show, when examined by the microscope, a large percentage of small granules and the absence of large assemblies of them. Formerly the wheat flour was almost universally subjected to a prolonged fermentation previous to its use for size making, but now this custom is not so usual except for certain work where a light sizing is preferred. By the use of zinc chloride similar effects can be obtained. The soft feel of cloth produced by fermented flour-size (spoken of above) is almost certainly due in the main to the formation of soluble starch, dextrins, and sugars during the fermentation, but the removal of the gluten and the breaking up of agglomerated starch granules also plays a part. A good size of this kind may be made by adding 3½–4 gals. of zinc chloride solution (100–102° T.) to 280 lb. of wheat flour.

The paste from maize starch is opaque, thick and white, and does not readily liquefy on standing or lose strength on continued boiling, but it usually mildews much sooner than pastes made from other starches. Maize size is used for medium and heavy sized goods, especially after mixing with wheat starch.

Sago starch gives a rather thin paste and strengthens the yarn more than farina, and, unlike the latter, does not "go soft" quite so readily.

Tapioca produces a rather thin paste on boiling

Rice starch is not very often employed as a textile size, but is very extensively used in laundries for stiffening collars and cuffs. It also enables a higher polish to be given than other starches, perhaps owing to the smallness of the granules.

Rice flour requires rather a prolonged boiling, about the same as maize, and the resulting feel is rather harsh.

Soluble starches are much more applicable to "finishing" cloth than sizing, for they lay the fibres without giving much additional strength. These soluble starches are mainly derived from maize starch or from farina, but to some extent also from tapioca.

The most successful methods appear to be those based upon the action of chlorides of calcium, magnesium or zinc on starch. Some are prepared by the action of malt, the following being fairly representative of the procedure. Mix the farina or tapioca with 2½ per cent of malt, or 5 per cent in the case of maize or rice, with water and warm carefully until thickening begins, allow to stand for about twelve minutes and then boil up quickly. The diastase in the malt will not act in the presence of chloride of zinc or antiseptics.

Dextrin is also very largely used in the finishing of certain classes of cotton goods.

The preparation known as "Apparatine" has been much applauded and was for a long time regarded as being made by some obscure and secret process. Dipierre published, in 1879 (but it was known long before that year), a recipe for making it by the action of caustic soda on starch.

A very satisfactory product can be made from maize starch since the soda overcomes the harshness of the maize granule and produces a nice soft finish. A good recipe for this is the following : 100 lb. of maize or other starch, 40 gals. water, add gradually with good stirring 23 lb. of 66° T. caustic soda solution and 24 gals. of water ; allow to stand two or three hours, then neutralize with 56 lb. of sulphuric acid of 25° T., allow to stand and complete the neutralizing with acetic acid, testing the mixture with litmus paper from time to time to control the neutralization.

Glucose is used as a softener and enters largely into glycerine substitutes or glycerine softeners, which frequently contain no glycerine at all. Glucose is also used as a finisher, its effect being dependent on the method of application and after treatment.

Softeners render the yarn pliable and so assist the weaving. When the added weight is about 20–30 per cent the sizing is described as "light," medium sizing is used to add weight and produce a certain feel, heavy sizing is to give the cloth a better and fuller appearance.

# CHAPTER X

## GLUCOSE, DEXTRIN, GUM

MENTION has been made in a former chapter of some of the products of starch which result from the action of dilute acids.

The substances known as Glucose (starch sugar) and Dextrin are perhaps the best known, but others, such as the "soluble starches," are of great importance in certain industries. The various substances derived from starch can only be separated from one another with great difficulty, as their properties seem to merge into one another. The end links of the chain are easily recognized as different bodies, but the individuality and number of the intermediate links is not known with certainty. The glucose and dextrin mentioned above are complex mixtures.

The extraction of grape sugar, more correctly called dextrose, by the action of acids on starch is a certainty, and this is also the case with maltose (malt sugar) and the action of diastase. Some recognizable pauses in the progressive action of acid (or diastase) can often be perceived by testing the products with iodine solution. Thus we find—

Starch gives a deep blue coloration.
Soluble starch a blue ,,
Amylodextrin a violet ,,
Erythrodextrin a red ,,
Achroodextrin a yellow ,,

These stages, however, are not sharply divided from one another.

The end-product is invariably dextrose, which gives no characteristic colour with iodine.

By the action of heat only, much the same results are achieved, but in this case the products are coloured. Up to about 130° C. the alteration is not very marked, but the very slight yellow tint at that temperature passes into a pale brown at about 200° C. The microscopic appearance of the granules is not much altered, but the starch now becomes soluble, or partly soluble, in water—a property not shared by untreated starch.

Starches rendered soluble by heat, or by heat and a modicum of acid, constitute dextrin or British gum (also known commercially as Gommeline or Alsatian Gum). It is an intermediate product between starch and sugar.

The origin of the second name is of interest, and shows the curious circumstances which led to the discovery of this valuable product. The manufacture of potato flour was badly received by the British working classes from the very first. The large increase in the consumption of this vegetable gave rise to fears of a possible rise in price, and feeling ran so high that incendiary fires of factories became frequent.

On 5th September, 1821, such a fire broke out at Chapel Lizard, near Dublin ; a workman in one of the neighbouring print works, who had helped to extinguish it, found on the following morning that his clothes had now become quite stiff, as though soaked in gum. He returned to the partially burnt sheds, and noticed yellow and brown clots of flour, which were soluble in water. Subsequent experiments with an iron saucepan were quite successful. The discoverer and four other workmen who had joined with him in the purchase of flour, sold the process in Manchester, and emigrated to New Orleans. On the death of the discoverer, the secret was passed on to a friend, who returned to England, where he manufactured large quantities. By elaborate precautions and much bluffing, the process was kept secret for a long time, but the method became known on an occasion when, though ill, he began the operation in the presence of a customer whose pressing order he was desirous of fulfilling. In the two following years more than a dozen manufacturers were producing British gum.

Dextrin is the main constituent of a number of commercial products derived from starch, but it is hardly possible to obtain a dextrin of uniform chemical composition, for varying proportions of sugar and similar substances are almost invariably present.

The method of manufacture, the temperature employed, the origin and purity of the starch, all play a part in the ultimate composition of the product.

The simplest method, however, for the conversion of starch into dextrin is by heating it to about 200° C., prolonged heating almost invariably resulting in yellow coloured products.

Dextrin may be produced by boiling starch with diluted acid, but care is necessary to arrest the action before it has proceeded too far, for this will result in the presence of sugars.

The more easily controlled method of heating the starch either alone, or with small quantities of acid, is almost universally adopted. It is of supreme importance to subject the whole of the starch to the necessary temperature and to avoid any local overheating. Direct firing, therefore, is thus practically excluded. But by surrounding the roasting vessel with an external jacket containing an oil of high boiling point, a uniform temperature can be maintained. In some designs superheated water under great pressure is employed as the heating medium. In all cases the vessels must be provided with efficient agitators, for without these a uniform product cannot be obtained. Samples are taken frequently and the progress of the conversion followed. When the conversion is complete the material must be cooled down to an ordinary temperature as rapidly as possible.

In the larger factories mechanically-driven cooking machines, consisting of circular shallow pans of thin metal plate furnished with stirring arms, are used.

In the acid conversion process it is necessary to restrict the acid to a very small amount, and to avoid the introduction of much water into the starch. The acids, which are selected on account of their being volatile, are hydrochloric acid and nitric acid, though, from a chemical standpoint alone, others are available (Fig. 14).

These acids are used in a highly diluted form, usually considerably below 1 per cent. On account of the small quantity of acid in proportion to the bulk of the dry starch, uniform incorporation is not an easy matter. A second drying is sometimes used, but by suitable spraying devices the need of this repetition may be avoided. After crushing all lumps and passing the powder through a fine sieve it is conveyed to the heating apparatus, and the temperature raised to about 110° C., or slightly lower for the palest dextrins. It is, of course, possible to combine the drying and dextrinizing in one operation, but the product made in this way is usually of lower quality than that prepared in specially designed roasting pans.

A uniform and rapid cooling is also as necessary in the acid process as in the roasting method.

Solutions of dextrins, or liquid gums, are made by boiling the starch with acid until the iodine test no longer shows a deep blue colour. A better liquid gum will result from the solution of a dextrin in water, which may be clarified by filtration.

An artificial " gum arabic " is made by concentrating

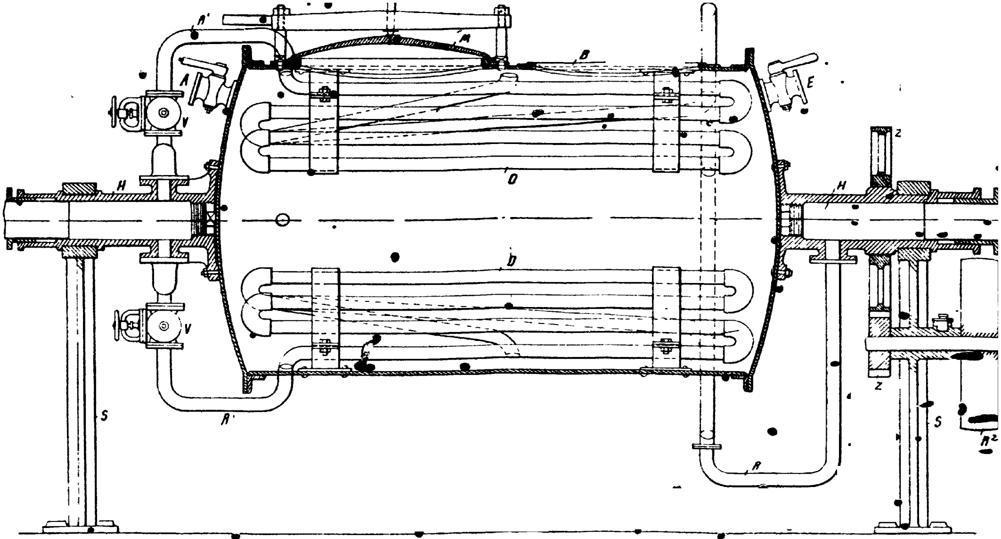


FIG. 14

APPARATUS FOR CONVERTING STARCH INTO PRODUCTS SOLUBLE IN WATER, SUCH AS DEXTRIN, BY THE ACTION OF SULPHUROUS ACID GAS the solution until thick and viscous, and drying on nets. Probably dextrin prepared from maize starch is the best for general purposes, as that from farina (potato starch) is apt to possess a characteristic odour, though it appears brighter.

Starch which has been treated in the manner described in a following section may be used to prepare "fine white" dextrin free from odour. Many processes have been suggested to produce a starch which is soluble in warm water, for soluble starches are superior for many purposes in various branches of the textile industry in which the penetration of the fibre is important.

The group of modified starches contains the bodies intermediate between ordinary starch and dextrin, the microscopic appearance being little different from the original granules, while the iodine reaction shows varying shades of blue to violet or even a reddish tinge. A variety which is soluble in boiling water without forming a paste results from the action of very dilute acids and chlorine, followed by drying at a temperature below 80° C. The treatment with chlorine may be associated with a simultaneous or separate treatment with ozone. Other methods employ dilute acids and controlled temperatures followed by filtration and washing with cold water to remove the acid. A rather different process is based on the precipitation of the soluble starch, prepared by the action of caustic soda and subsequent neutralization of the alkali by acid, by means of magnesium sulphate.

Mention has been frequently made of the formation of sugars from starch by the action of acids. This sugar has been proved to be identical with that found in sweet fruits and honey, and for this reason has received the name of grape sugar, fruit sugar, or glucose.

It is less easily soluble in water and less sweet than cane sugar (or beet sugar which is identical with the product of the cane).

On account of certain optical properties this sugar is known as dextrose, a substance which must not be confused with the dextrins which have been already described. If the latter substances are present serious difficulties are introduced into the process of manufacturing glucose, especially when the solid product is required, but less so in the manufacture of syrups.

The conversion may be carried out in open vessels provided with heating coils for steam, the thin starch suspension being allowed to flow into the continuously boiling dilute acid. Heating is maintained for a short period until a test of a small sample of the cooled solution shows that dextrins are no longer present, i.e. no blue coloration results after the addition of iodine solution, and no cloudiness on adding excess of alcohol.

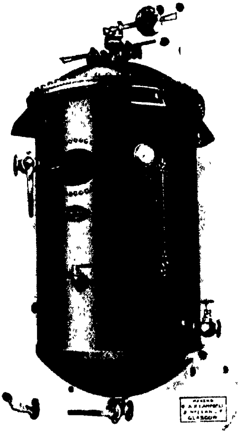


FIG. 15

CONVERTER

Open vessels, however, have now been superseded by " converters " in which it is possible to operate under higher pressures and consequently under higher temperatures This mode of conversion requires less than a quarter of the time necessary if open vessels are used, and is always far more complete. A pressure of about

40 lb. per square inch is used. Owing to the action of dilute acids on iron the vessels are lined with lead (Fig. 15).

The control of the operation is similar to that described, but it is of great importance to stop at the point of maximum sugar content on account of the possibility of reversion to other sugars (e.g. isomaltose).

As soon as the boiling process is completed the acid is neutralized in another vessel by carbonate of lime and the resultant sulphate of lime (gypsum) is for the most part precipitated. This neutralization is advantageously carried out by the gradual addition of carbonate of lime as a fine suspension in water, made in a separate vessel provided with the necessary agitating gear. Some of the gypsum will remain in solution as it is more soluble in a glucose solution than in water, and, in consequence of this, further quantities are thrown out at the later stages of the process, and prove a source of considerable trouble. The precipitated gypsum and any other solid impurities are removed by filtration, usually by means of filter presses, but other types of filters, though less efficient, may also be used. Some of the soluble impurities may be removed by filtration through bone-black, and made less evident by the bleaching action of sulphurous acid or sulphite of lime.

Any dextrin which has been formed in the " conversion " will remain in the liquid and consequently the formation of this substance must be avoided at the start, since there is no easy means of separating it from glucose.

The concentration of the solution is carried out in vacuum pans frequently in stages which allow the intermediate removal of separated gypsum before the final boiling down to solid glucose (Figs. 16 and 17).

This use of vacuum apparatus enables the evaporation

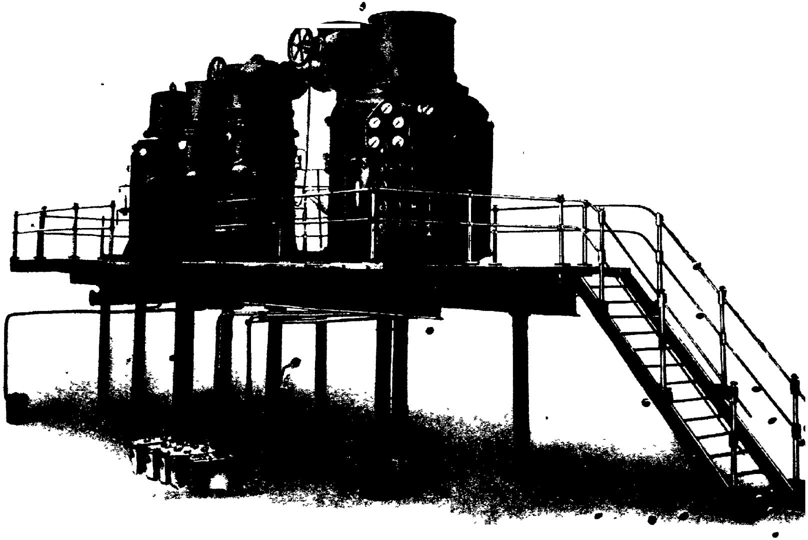


FIG. 16

VERTICAL TRIPLE EFFECT EVAPORATOR WITH FINISHER of the water to take place at much lower temperatures and obviates the risk of over-heating and burning, which are liable to occur in the old-fashioned direct fired pans, or even with steam coils.

Some factories use a series of steam pipes over which the glucose solution trickles down, and thus overcome one of the difficulties which arise in cleaning the gypsum from the pans. In this system the solution is not long in contact with the heated surface, but for the final concentration the employment of the vacuum pan is essential when a high-grade product is required.

The progress of concentration is observed by taking samples, for which provision is made in the design of the pan to enable them to be obtained without any interruption of the boiling.

The contents of the pan when sufficiently concentrated are run off into cooling vessels, where they solidify to a fairly solid mass if they contain only small amounts of dextrins and other non-sugar substances.

The non-crystallizable portion is removed as far as possible and the crystals refined, if necessary. Every possible endeavour should be made to obtain the highest possible yield of crystals by working within certain limits of temperature, by the correct degree of agitation, and by " sowing " the mixture in the crystallizing tanks with a small amount of pure crystals.

For a number of purposes solid glucose is not necessary, and the manufacture of liquid glucose does not demand such extreme care as does the former product. The " conversion " is conducted in such a way that sufficient dextrin (mainly erythrodextrin) is present to prevent the formation of crystals.

The concentration is carried to the point at which the gypsum is precipitated, followed by careful filtration. It is most important to remove all the gypsum, and for

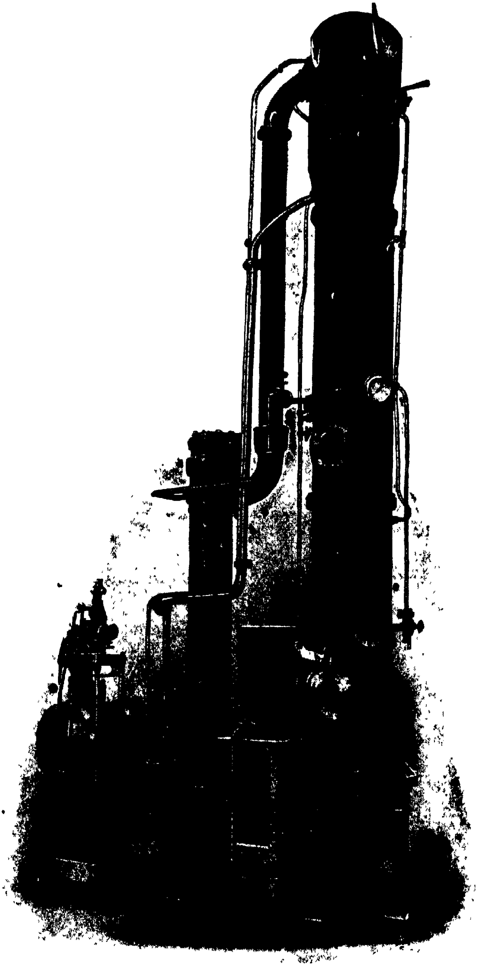


Fig. 17

MULTIPLE TRIPLE EFFECT FILM EVAPORATOR

this reason filtration at ordinary pressure is sometimes preferred to filter pressing as being more conducive to clear and bright syrups. A rapid cooling of the syrup from the pans is also advisable, otherwise coloured syrups may result from the action of the air on the hot liquid.

In numerous branches of trade a wholesome colouring matter is required, and for such purposes "caramel" is very suitable. Naturally caramel may be made from cane sugar, but for many purposes that derived from glucose is superior.

For colouring beer, wine, vinegar, artificial rum, brandy, and confectionery a clear solution is necessary, and since dextrin is insoluble in alcoholic liquids the presence of this substance must be avoided.

The actual operation of making caramel is easy, but judgment is necessary, as by a too prolonged heating, or by the use of too high a temperature, bitter substances are produced, and by insufficient heating the colouring power is much diminished.

A fairly deep pan, to avoid loss by spurting, and an efficient stirring device which sweeps the bottom of the vessel to prevent burning, are necessary. The temperature of caramelization is a little below 200° C., and the end of the operation is ascertained by the stickiness, taste, and depth of colour of the mass, as well as its behaviour towards 80 per cent alcohol. When the tests are satisfactory, hot water is run into the pan and the agitation continued for a time, the solution being then filtered and allowed to cool in barrels.

# CHAPTER XI

## FERMENTATION PRODUCTS OF STARCH

THE art of preparing an exhilarating or intoxicating beverage by the fermentation of various cereals and other farinaceous products was known many centuries before the Christian era.

An interesting discovery which illustrates this great antiquity of brewing has very recently come to light during excavations in Egypt. In ancient times it was he custom in that country not only to place in the tomb ustenance and a variety of other offerings for the use of the deceased, but also to bury with him a perfect picture or representation in miniature of his everyday ife. In the discovery made a short time ago, at Lahun or Gurab, in Upper Egypt, the whole process of brewing beer is included in the model, which is about 3,700 years old. In a small box, placed near the body of the dead man, all the vats and other apparatus necessary were reproduced on a small scale, but in exact minature, and in one corner was a small quantity of barley. The box also contained exquisitely modelled figures of brewery workers.

The old literature of China reveals specifications for the preparation of malt which are essentially those followed in the scientific industry to-day. The books of 1000 B.C. read like the treatises of later European chemists on alcoholic fermentation.

Since the Greeks derived a large part of their civilization either from the same source as the Egyptians, or directly from them, it is not surprising to find early references to brewing in Hellenic writers. One of them is made by the poet Archilochus, who flourished about 700 B.C., and others by subsequent men of letters, from which we learn that beer and wine were used not only at the festive meetings but also in daily life.

The Biblical, or Hebrew, "strong drink," *shekar* (from which we get our word sugar), was made from palm or other juices from other fruits than grapes, and also from wheat, as is the present arrack now used in Palestine. *Tirosh* is the word for grape wine in the Scriptures.

The raw material for the beverages naturally varies with the geographical position, but it is probable that no primitive peoples are quite without some knowledge of the means of preparing fermented drinks from such plants as occur in their climate.

The natives of South America prepare an alcoholic liquor, known as "chicha," by the fermentation of maize starch, which analysis shows to possess an alcoholic content of 23·50-54·63 grams per litre.

The Kaffirs use the seed of the millet (*Sorghum vulgare*) for a beer by a process of malting and brewing very similar to that used in Europe for malt beer.

Farther north, "bousa," an intoxicating drink of great power, from the seed of a grass (*Poa abyssinica*), is more usual. The Russian drink "kvass," from barley and rye flour, the Chinese "samshee" from rice, and the "pulque" from the aloe (*Agava*) will serve for further illustrations. The intoxicating drink "saké," which is brewed in large quantities in Japan, is prepared from rice.

The ferment "kogi" is produced by the growth of the fungus *Aspergellus oryzae*, which forms a whitish or pale green mould on rice. It may be dried and preserved in tins like "German yeast." Seventeen parts of steamed rice and three of kogi are stirred frequently by a wooden spoon in a bowl for a period o four or five days. The mixture is poured into anothe vessel and covered with a mat. This first fermentatio is complete in two or three weeks. Fifty parts of thi mixture are added to a further 150 of boiled rice an 200 of water are added. The second fermentation take place during the following week, when the liquid i poured off into another vessel where it remains for abou ten days more before it is ready. The whole proces requires about a month, and the product contains abou 13 per cent of alcohol. The Chinese product, containing about 36 per cent of alcohol, requires less tim for brewing.

Probably it is a similar mould, known as "raggi," which is the agent for producing from rice the arrac of Java and the drink made by the Dyaks of Centra Borneo.

The preparation of intoxicating liquors from cassav is widely practised. The method is usually a simpl fermentation of cassava flour, either raw or partiall cooked, Batata, or maize meal, being sometimes adde The appearance is not agreeable and the methods c preparation of some varieties are repulsive, e.g. th very intoxicating drink "piwarsi" is made as follow by the natives of South America; manioc chips ar chewed and the product, mixed with saliva, is collecte in wooden vessels. The bouquet of the fermente liquor is said to differ with each brew!

As we are now speaking of alcoholic beverages an fermentation, and have already alluded to the operatio of distillation and of the various cereals from which alcohol is derived, perhaps a brief allusion ought to be made here to the well-known spirituous liquors—whisky, brandy, gin, and rum.

The introduction of the manufacture of spirit into

Europe seems due to the Arabs, as the word *alcohol*, derived from the Arabic *al-kohl*, suggests. For the Arabs, after the establishment of the Caliphs, turned their attention to the study of medicine, and created a new era in the science of chemistry by their researches. Geber, an Arab physician, who lived in the eighth or ninth century, is said to have treated of distillation and other chemical operations, but the writings attributed to him seem to have been made about the twelfth century. Rhazes, a Persian physician of Baghdad (A.D. 850–923), gives the rules for the vinous fermentation of amylum and sugar, and for the distillation of alcohol. Alexander of Aphrodisia, who lived in the reign of the Roman Emperor Caracalla drew attention to the fact that wine might be distilled. Surmises also as to the formation of wine by fermentation were made in the thirteenth century by Raymond Lully, who called the spirit of wine *ultima consolatio humani corporis.*

In the north alcohol is produced from different kinds of grain, in the south mainly from wine.

A mixture of malted and unmalted grain is usually employed in the production of whisky, but molasses, rye, rice, starch, potatoes, dates, currants, etc., are not excluded. In some districts, and especially when malt only is employed, "pot stills" are used, but the "patent still" (Aeneas Coffey, 1831) almost invariably in other cases.

The proportions of the different grains used to produce the whisky may vary with the particular flavour desired, e.g. four-fifths malted and unmalted barley, one-fifth wheat, oats or rye in decreasing amounts as given.

It is a curious fact that among no other races than the Gaels of Ireland, and of the Scottish Highlands was the liquor called usquebaugh, or whisky, made in perfection in earlier days. Some would say that this is the case even now. The word means "Water of life" (Gaelic, *uisge beatha*).

Maize, which was introduced principally on account of the repeal of the Corn Laws in 1846, is also sometimes utilized for the purpose, as is rye in America.

Gin—the name is a corruption of the French *genièvre* or the Dutch *junever*—is derived from grain and owes its flavour to the addition of juniper berries during distillation. A large number of flavouring materials is at the disposal of the gin-maker, such as cardamom, orris, fennel, coriander, liquorice, etc. Maize, malt, and rye are used as well as molasses or low-grade sugars, the latter producing a somewhat cruder variety. Hollands and Schnapps are practically synonymous terms for this spirit.

Brandy is almost universally understood to be a spirit derived exclusively from the grape, but "brandies" which owe their origin to grain spirit, with the addition of flavouring essences, are also manufactured. The variety known as Dantzig brandy is derived from rye and the flavour introduced by the addition of *Calamus aromaticus*. Other varieties contain spirit from beetroot or potato.

Rum is mainly the product of fermentation of molasses or other sugary by-products, but some is also made from beetroot. The name is derived from a Devonshire word "rumbullion," signifying a tumult or "rumpus" (1650). "The chief fuddling they make in this island (Jamaica) is rumbullion, alias kill-devil, and this is made of sugarcanes distilled, a hot, hellish, and terrible liquor."

Apart from the matter of beverages alcohol is an essential in the manufacture of a very large number of important chemical substances, e.g. ether, chloroform, explosives, perfumes, varnishes, medicinal tinctures, dyes, etc., and as a source of heat and motive power, it is destined to play an important *rôle* in the near future; and though the cost of root crops grown on cultivated land in temperate regions is too high to allow of their profitable utilization as sources of alcohol, the possibility of growing them on suitable reclaimed land is not to be lost sight of.

To produce the amount required annually in England to replace petrol—viz., 250,000,000 gallons—would need more than 4,000,000 tons of barley, 12,500,000 tons of potatoes, or 25,000,000 tons of mangolds. Roughly, the annual production of potatoes in the United Kingdom is only one-half, and of the other materials barely one-third of these quantities. Thus, no considerable proportion of such food-crops could be diverted to increase the production of alcohol. And as foodstuffs they command much higher prices than could be paid for them as sources of power alcohol.

The production of alcohol from wood has been under trial for several years but has not yet definitely established itself as a paying manufacturing business in normal times.[1] The use of rice straw and husk has also been suggested, and experimental plant established to try the success of the proposal.

In Germany sawdust, chips, and shavings are worked up for the manufacture of alcohol, and a short time ago (1919) four factories were working on these raw materials. The process consists in heating the wood with either sulphurous or hydrochloric acid for 20–40 mins. at 265° C., under a pressure of 7 atmospheres. The liquor, after neutralization, is fermented. But the cost of production must be high, and especially so if the residues cannot be used for fodder and the waste liquors for other products.

---

[1] During the war several wood-distillation factories were erected in England for the production of methyl alcohol. It is also reported that the manufacture of wood alcohol in the United States has increased since the passing of the Prohibition Act.

The sun dried flowers of the Mahua tree have been suggested as a source of power alcohol. On the assumption of 90 gallons of alcohol per ton and a price of 60s. per ton of dried flowers delivered at the factory, this source might be useful in restricted localities. The great problem, however, in this and many other suggestions is the cost of " harvesting " the raw material and transporting it to the factories.

The Journal of the Agricultural Department of South Africa has drawn attention to the sweet potato and its possible use for the production of fuel-alcohol. Compared with the common potato it is more easily grown, and is a better producer of starch, since it contains about 72 per cent of water and approximately 25 per cent starch and sugar, as against 75 per cent and 16 per cent to 24 per cent in the ordinary variety.

It has also been suggested that the fruit of the Indian or Chinese Lilac (*Melia azedarach,*) commonly known in India as the Bead Tree, in Australia as the White Cedar, might be used as a source of alcohol, since the berries, about the size and shape of cherries, though poisonous, contain nearly 30 per cent of total sugar.

Alcohol may be also readily produced from the tubers of *Asphodelus ramosus*, a plant widely distributed in the countries bordering on the Mediterranean, and, experimentally, five litres of alcohol have been extracted from 100 kilograms of roots. After pulping, these are boiled with dilute acid, and fermented by a yeast acclimatized to similar worts.

In this respect manioc is also of much interest and importance, for the root contains up to 40 per cent of total fermentable matter. In the dried root this material is about 85 per cent, and under good conditions about 120 litres of alcohol should result from the treatment of 100 kilograms of starch.

The simplicity of the cultivation of manioc, and the high crop-yields seem to indicate a very important industrial future for this plant. For the following approximate composition of some starchy raw material will indicate, without further comment, its advantageous position.

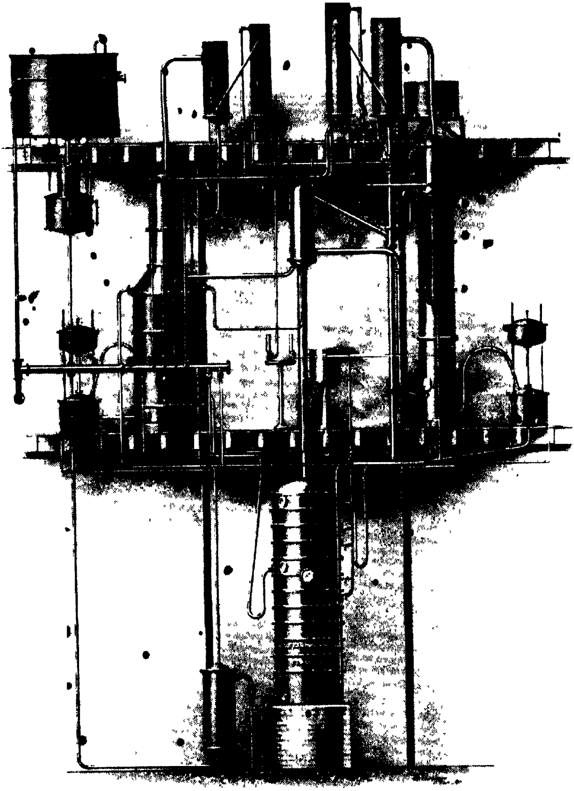
| | % *Starch.* | % *Water.* |
|---|---|---|
| Fresh manioc tuber | 25–40 | 65–50 |
| Dried root . . | 80–85 | 12 |
| Potato . . . | 18 | 74 |
| Rice . . . | 50-75 | 14 |

The production of a liquid capable of being fermented to form alcohol is the result of a series of complex changes in the starch. There are several ferments which can produce the desired results, but the general idea can be followed out from a description of a specimen method of procedure.

By means of the ferments (enzymes) in malt, the principal ones being known as amylase and dextrinase, the starch is converted into dextrins, which in turn are further acted upon by the dextrinase resulting in the formation of maltose (malt sugar).

The process of conversion or saccharification must be carried out with careful supervision, as the temperature at which maximum beneficial results are obtainable must be maintained and the activity of undesirable ferments suppressed as far as possible. Either fresh roots or meal may be used. The preliminary cooking is done in a conical cooker in the case of fresh roots or in one of horizontal type, provided with an agitator, when working with meal.

The material from the cooker is treated in a macerating



*By permission of* *Blair, Campbell & McLean*

FIG. 18

TRIPLE COLUMN RECTIFYING STEAM STILL FOR CONTINUOUS WORKING machine, into which the malt ferment is introduced, and the temperature of the mixture regulated to that suited to the fermentation. The action of the ferment proceeds in the macerator until saccharification is complete. A rapid cooling of the liquor is necessary, as at a temperature of 50–53° C. the troublesome lactic acid ferment is active, and at 40–48° C. the corresponding butyric acid ferment, the latter more often causing trouble than the former.

Refrigerating machines are usually employed to carry out this important part of the process, especially necessary in factories situated in tropical climates.

The subsequent processes may be varied according to circumstances. In some cases a period of lactic fermentation, lasting a few hours, is brought about with the object of producing a liquor rich in nitrogenous bodies and to maintain a certain degree of acidity which helps to suppress the growth of undesirable yeasts. The lactic ferment is then destroyed by heating to 80° C. The use of antiseptics is hardly permissible in practice, as in many cases they render the residues unsuitable for cattle foods.

Fluorides of sodium, ammonium or aluminium, or hydrofluoric acid are, however, employed in some distilleries. A third method, and one which makes a strong appeal when viewed from the scientific standpoint, is the adoption of pure cultures of the ferment, to act upon the sterilized mixture. Air, sterilized by passing through a filter containing antiseptic wool and through various solutions, is forced by a compressor through the fermentation vessels. Every part of the plant is kept in a sterile condition and the pure cultures introduced. It is possible to make use to some extent of the fluoride method, combined with that of pure cultures; but ferments acclimatized to fluorides must then be

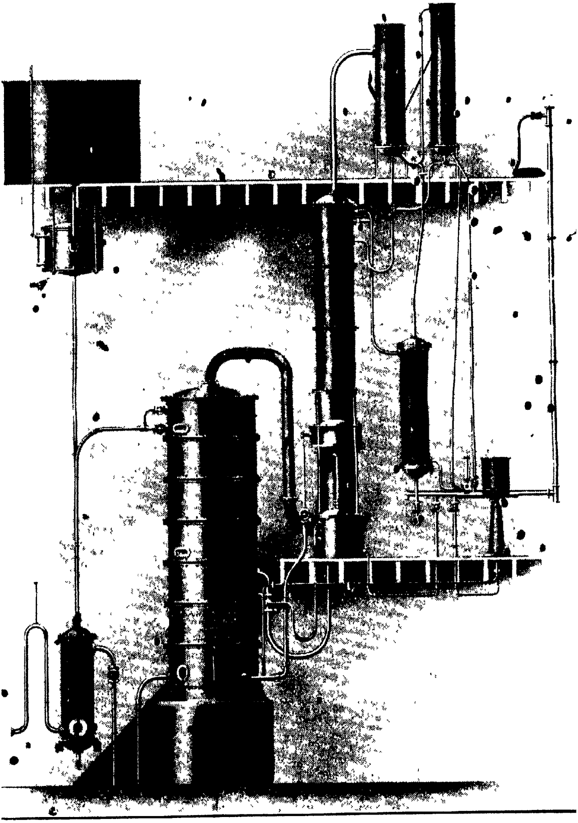


Fig. 19

DOUBLE COLUMN RECTIFYING STILL FOR CONTINUOUS WORKING employed. Theoretically, 100 parts of starch should produce nearly fifty-seven parts of alcohol, but such a result is naturally unattainable in practice, since ordinary (ethylic) alcohol is not the only product, glycerine and succinic acid being also formed in small quantities. The conduct of the whole series of operations in the fermentation method described above requires the greatest possible care, as the growth of "wild" ferments may destroy a large amount of material, and the optimum temperature for a rapid and good fermentation lies within very narrow limits.

The method of saccharification by means of acid is perhaps rather easier to control, but it is not practical to convert the whole of the starch by this method into fermentable sugars. All starch granules are not acted upon at the same rate, the young or more recently formed granules will have been converted into glucose by the time the older ones have arrived at the dextrin stage, and as such practically lost. By a more prolonged saccharification the glucose formed from the recent granules will suffer further change.

The cooking process, with a much-diluted sulphuric or hydrochloric acid, has already been described. As a strongly acid material will not ferment it is neutralized with limestone or lime. The method of working at ordinary pressures has been almost entirely replaced by cooking under pressure, and in this case hydrochloric acid is mostly used.

The advantages of hydrochloric acid over sulphuric arise from the fact that, in the absence of air, copper is not attacked by it, and the operation of separating the solid calcium sulphate does not arise, since the salt produced in this case is the soluble calcium chloride. A preliminary lactic fermentation is not necessary as a slight acid reaction can be left in the liquor by stopping the addition of the lime at a fixed point, at which a trace of the acid remains unneutralized. The main fermentation can be conducted either by the fluoride method, pure culture method, or a combination of both.

The whole scientific basis of the fermentation industry has its origin in the work of Pasteur. For the first industrial starch ferment (*Amylomyces rouxii*) used in a distillery was that discovered and isolated by Calmette, director of the Pasteur Institute in Lille, during a visit to Indo-China in 1892. In 1897 the distiller, Collette, introduced this yeast into his factory, but many modifications of the first method of procedure were proved to be necessary. Another ferment, "Mucor D," was also isolated, which possessed the useful property of surviving a higher alcohol content than the earlier growths.

The residues left after the removal of the alcohol by distillation are employed as cattle food, and are readily taken when stock have become used to them. The still-residues are filter-pressed, and the cakes dried to a moisture content of about 20 per cent or rather less, usually after extracting any oil in a special apparatus. A desiccation to a lower moisture content in a vacuum also affords an excellent cattle food

Various forms of still are used in separating and eventually rectifying alcohol, their type depending mainly on the desired quality of spirit, and to some extent upon the character of the labour available (Figs. 18 and 19).

Crude alcohol contains varying amounts of chemically different spirits and ethers, and the object of the intricate arrangements of distilling plant is designed to effect as complete a separation as possible of these substances from the ordinary (ethylic) alcohol.

The operation is in practice a very complicated one, as the different temperatures at which the various constituents pass into vapour, and their different mutual solubilities are by no means the only factors which must be considered. Whenever practicable the distillation is continuous so as to avoid loss of output incidental to the periodical working up of batches

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### NOTE TO PAGE 109.

Since the above was in type, a product obtained from the fruit of the *Aldina insignis*, and known under the name of Dakamballi, has been examined (1922) as another possible source of alcohol, and found to contain about 76 per cent of starch. In the form of mucilage it is much used in British Guiana as an antidote for dysentry.

# INDEX.

ACETIC acid, 13, 94
Acetone, 64
Achroo-dextrin, 11, 91
Aesculin, 74
Albumenoids, 24, 46
Alcohol, 14, 107, 108
——, ethylic, 114, 115
——, methyl, 108
——, wood, 108
Alexander of Aphrodisia, 106
Amylase, 12
Amylodextrin, 11, 91
Amylopectin, 13, 14, 16
Amylose, 13
Amylum, 12
Andes, 72
Ants, cooshie, 79
——, parasol, 79
Apparatine, 90
Arabs, 106
Archilochus, 104
Argentine, 36
Arrowroot, 7, 74
Artichoke, 8
Asphodel, 109
Aungiers, 3
Australia, 46, 52, 60, 72, 109

BACTERIA, 13
Banana, 1, 70
Barley, 2, 15, 42
Bead tree, 109
Beans, 17, 55, 60, 83
Beccari, 42
Beet, 10
Belt, Thomas, 79
Bermuda, 75
Bharti, 52
Bigg-barley, 42
Black Sea, 43
Boll weavil, 70
Bombay, 52
Borneo, 68, 105
Boston, 83
Bousa, 104
Brazil, 76, 80, 83
Brandy, 105, 107
——, Dantzig, 107
Bread fruit, 1, 70
Brisbane, 60
Brown and Polson, 7
Bryony, 70
Buckwheat, 15, 33, 54
Burbank, Luther, 45
Burma, 56
Butyric acid, 13, 15, 112

CALIFORNIA, 62
Calmette, 115
Cane-sugar, 10
Canna, 17
Caracalla, 106
Caramel, 102
Cardamom, 107
Carbohydrate, 2, 10, 87
Carbon dioxide, 8, 43
Carolina, 20, 55
Caspian Sea, 43
Cassareep, 80
Cassava, 75, 105
Cato, 3
Caustic soda, 14, 15, 21
Cedar, white, 109
Cellulose, 8, 10, 14
Celsus, 3
Cereals, 1, 2
Ceylon, 70
Champannois, 81
Charlestown, 53
Chestnut, horse, 15, 73
——, Morton Bay, 72
Chicory, 8
Chili, 20
China, 47, 51, 60, 103

Chios, [illegible]
Chlorophyll, 7
Chloride of lime, 85
Citric acid, 10
Coffey, Aeneas, 106
Coleman, 7
Collette, 115
Collins, 45
Colloidal, 10
Conac, 80
Conversion, 110
Converter, 97
Coriander, 107
Crete, 3, 34
Currawan, N S W., 72

DAKAMBALLI, 116
Dalhia, 8
Dandelion, 8
Danube, 46
Date, 1
De Candolle, 1, 45
Dextrin, 8, 12, 90, 91
——, white, 96
Dextrinase, 12, 110
Dextrose, 11, 91, 97
Diastase, 12, 88, 91
Dioscorides, 3
Dipierre, 90
Di-saccarides, 10
Drenthe, 20
Dublin, 92
Ducks, 62
Durra (or Dhurra), 46, 52
Dyaks, 105
Dysentery, 116

EGYPT, 3, 34, 103
Enzyme, 8, 12, 43
Erythrodextrin, 11, 34, 102
Euphrates, 34

FARINA, 21, 30, 31
Fennel, 107
Fermentation, 7, 86, 102, 108
——, vinous, 106, 121
Flaudin, 73
Fluorides, 45, 78
Fosbrooke, 4
France, 23

GAELS, 106
Geber, 106
Geese, 62
Gelatin, 15, 32
Gerarde, 6
Germany, 19, 20, 108
Gin, 105, 107
Glucase, 12
Glucose, 10, 12, 13, 90, 91, 96, 98
Gluten, 36, 37, 39, 40, 43, 85
Glycogen, 9
Gommeline, 92
Grading of food-stuffs, 60
Granada, New, 20
Granulose, 13
Greece, 34, 44, 103
Gronigen, 20
Guiana, 79, 116
Guillam, Mrs., 4
Guinea corn, 52
Gum Arabic, 94
——, Alsatian, 92
—— British, 92, 93
Gurab, 103
Gypsum, 98, 100

HALL, Samuel, 85
Hart, John, 7
Havena, 80
Hebrews, 104
Hedenus, 70
Herman, Mount, 34
Herodotus, 55
Hippocrates, 3
Holland, 4, 6, 20
Hollands, 107
Hungary, 47
Hurdle starch, 41
Hydrochloric acid, 16, 108, 114
Hydrocyanic acid, 52, 94
Hydrofluoric acid, 112
Hydrolysis, 11, 13
Hydrometer, 22

Im-Thurm, Sir E., 79
India, 47
Indies, East, 74
——, West, 74, 75
Inulin, 8, 56
Iodine, 12, 96
Isleworth, 3
Isomaltose, 98
Italy, 44

Jamaica, 75, 83
James I, 6, 20
Japan, 60, 104
Java, 56, 69, 81
Jones, Orlando, 7, 65
Johnson, Ben, 5
Juan Fernandez, 44

Kaffirs, 104
Kashgar, 55
Kausun, 64
Ketan, 56
Khir, 52
Khotan, 55
Kirchoff, 7, 11
Kogi, 104
Korakan, 52
Korea, 47
Kuwada, 45
Kvase, 104

Lactic acid, 15, 112
Lahun, 103
Lichenin, 8
Lignin, 8
Lilac, Chinese, 109
——, Indian, 109
Lille, 115
Lousiana, 58
Lully, Raymond, 106

Macaroni, 6
Madagascar, 55, 83
Magnesium sulphate, 87
Mahua tree, 109
Mailoran's mill, 36
Maize, 1, 2, 8, 15, 33, 44, 45, 89, 107
Maize-fly, 47
——, horse-toothed, 47
Malic acid, 10
Maltose, 11, 12, 13, 91, 110
Malt-sugar, 10
Manchester, 92
Manioc, 8, 17, 76, 109, 110
——, bitter, 76
Mannite, 10
Maquenne, 13
Martin, 42
Matapie, 80
Mealies, 46
Mexico, 45
Milk-sugar, 10
Millet, 1, 50, 55
——, barnyard, 52
——, brown-corn, 52
——, Hungarian, 47
——, Italian, 47
——, pearl, 52
Mimetic magic, 58
Monosaccharides, 10
Montyon prize, 7
Moulds, 23, 24, 40, 41
Mucor, D., 115
Murray, 7, 73
Mysore, 52

New Orleans, 92
Newton, Samuel, 7
Nitric acid, 94
Norwich, 3

Oat, 44
——, Hungarian, 44
——, Turkish, 44
Orchis, 72
Orris, 107
Oxalic acid, 16
Ozone, 96

Padi, 62
Palestine, 104
Palm, Burrawang, 72
——, coco-nut, 70
——, Gomuti, 69
——, Palmyra, 70

Palm, Zamia, 72
Pancreatic juice, 12
Parana river, 36
Paris, 73
Pasteur, 115
Peas, 2, 17, 60
Pekin, 44
Phenol, 41
Pilcorn, 44
Piquage, 82
Pisa, 55
Piwarri, 105
Pliny, 3, 42
Polysaccharides, 10, 11
Potassium phosphate, 21
Potato, 1, 2, 8, 17, 110
——, English, 19
——, Dutch, 20
——, sweet, 1, 70, 109
—— -rasper, 25, 26
Protein, 9, 44
Ptyalin, 12, 121
Pulut, 56

QUEEN Elizabeth, 5, 6
Queensland, 80

RALEIGH, Sir W., 20
Rhazes, 106
Rice, 1, 8, 15, 33, 55, 89, 108, 110
——, Canadian, 64
—— -leaf hopper, 62
—— -stalk borer, 62
—— -worm, 62
Rothamsted, 25
Roux, 7, 13
Rum, 105, 107
Russia, 44, 54
Ryder, John, 7
Rye, 15, 43, 44, 107

SAGO, 8, 15, 18, 68, 89
——, artificial, 69
St. Kitts, 75
St. Vincent, 75
Saké, 104
Salep, 72
Saliva, 12
Samshee, 104
Sanwa, 52
Saponin, 72, 73
Saunders, C. E., 36
Scandinavia, 44
Schnapps, 107
Shama, 52
Shekar, 104
Sheriff, Patrick, 36
Siam, 64
Skeat, W. W., 36
Soap, 21
Solanin, 22
Sorghum, 1, 33, 52
Soursop, 70
Soy, 1, 60
Spain, 33
Spelt, 33, 34
Starch, crystal, 47, 50
——, hurdle, 41
——, lump, 47, 50
——, prismatic, 67
——, thick-boiling, 86
——, thin-boiling, 47, 86
Starchmakers' Corporation, 6
Sterksel, 3
Stink bug, 62
Stone age, 33, 34
Stowe, 4
Straits Settlements, 56
Stubbs, 4
Sulphur burner, 47
Sulphuric acid, 30
Sulphurous acid, 30, 108
Sumatra, 58
Sunflower, 9
Switzerland, 33
Syon monastery, 3

TACCA arrowroot, 74
Tahite, 74
Tapioca, 18, 75, 89
Tashkind, 55
Tartaric acid, 10
Teosinte grass, 45
Texas, 53

Tigris, 34
Tortella, 46
Turner, Mrs., 5

USQUEBAUGH, 106

VAN DER PLASSEN, Mrs., 4
Veencolonien, 20
Villiers, 13
Virgil, 34
Virginia, 32

WHEAT, 2, 8, 33, 44
—, Marquis, 34
Whisky, 105, 106
Wickham, Thomas, 7
Wordsworth, 74

YAM, 70
Yucatan, 46

ZEND-AVESTA, 55
Zinc-chloride, 15, 88

## ADDITIONAL NOTES

**FERMENTATION** (p. 106). There are roughly speaking five different species of fermentation—

(1) *Vinous*, which converts sugar into alcohol.
(2) *Acetous*, which converts acohol into vinegar.
(3) *Saccharine*, which converts starch into sugar
(4) *Mucilaginous*, which converts sugar into gum.
(5) *Putrefactive*, which converts organic substances into gases.

**PTYALIN** (p. 12). This enzyme of saliva converts starch into sugar. The test for sugar (sulphate of copper and liquor potassae), produces no reduction of the oxide of copper in a solution of starch not treated with saliva. But a mixture of starch and water held in the mouth for two minutes only, when so tested, shows a clear red line of reduced copper, the evidence of the presence of sugar. If held in the mouth for three minutes a still more decided manifestation is apparent, and if retained there for five minutes a distinct mass of reduced copper, proportioned to the quantity of sugar formed out of the starch, becomes visible.

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